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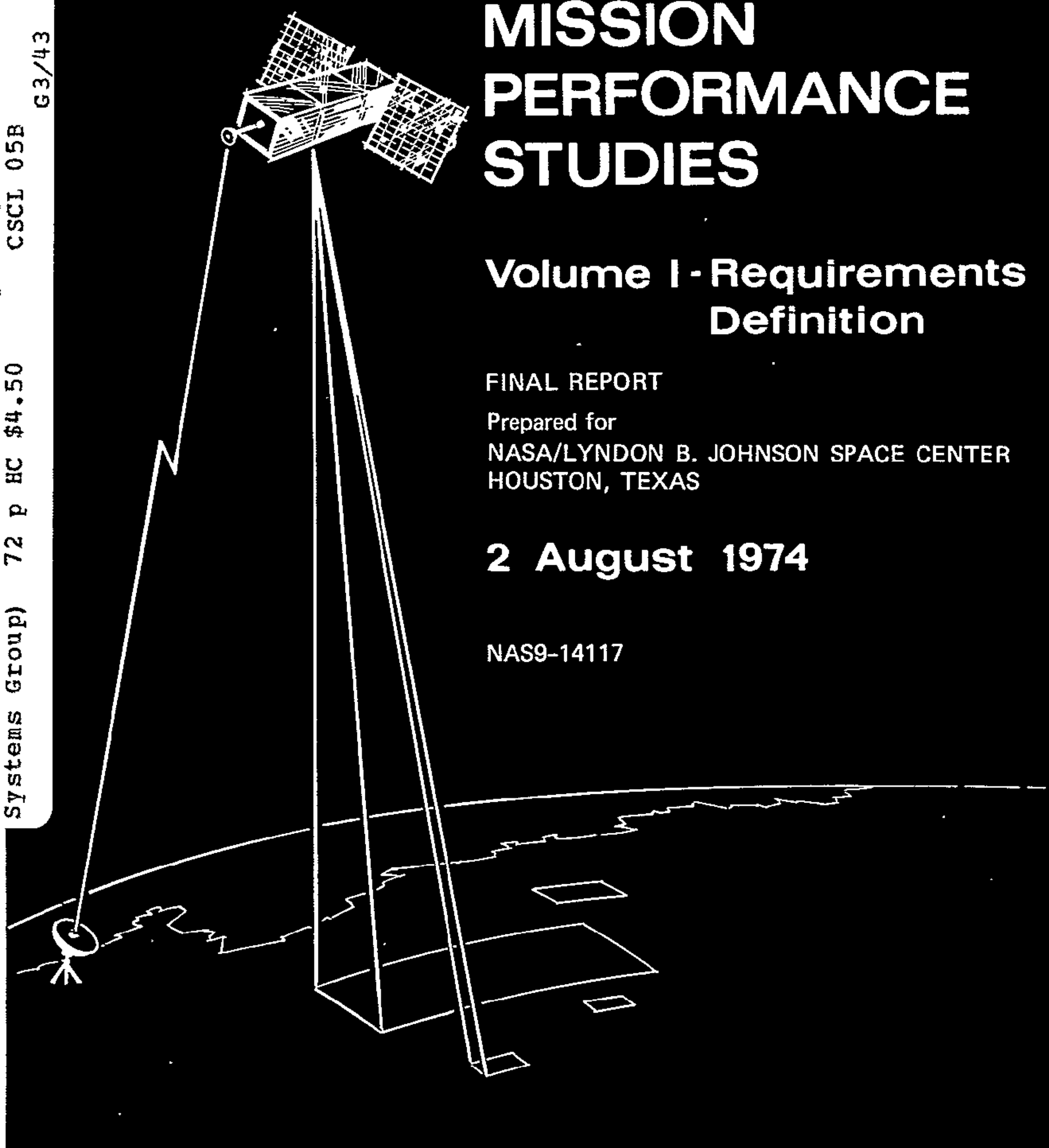
EARTH RESOURCES MISSION PERFORMANCE STUDIES



Volume I - Requirements Definition

FINAL REPORT

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This report, in two volumes, documents the completion of the effort under Contract NAS 9-14117, "Earth Resources Mission Performance Study." The contract period was from 5/8/74 to 8/2/74. NASA/JSC contract Technical Monitor is W. K. Stephenson, Earth Resources Program Office, JSC.

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1.0 INTRODUCTION

1.1 SCOPE

The requirements definition task for the Earth Resources Mission Performance Study was limited to an update and consolidation of information presently available. The prime objective of this task was to gather the diverse user agency requirements for remote sensing data and to organize them into sensor collection requirements for an EOS-A configuration including a thematic mapper (TM) and a high resolution pointable imager (HRPI). The period of performance for this task was two months.

1.2 BACKGROUND

Two specific instruments have been proposed for launch on the Earth Observatory Satellite (EOS). These two remote sensing multispectral imaging systems, the High Resolution Pointable Imager (HRPI) and the Thematic Mapper (TM) represent an advance in image system concepts. With the HRPI, the specific sites are not confined to the instrument's imaging swath-width centered on the sub-orbital ground track of the satellite, but may be directed to image specific areas $\pm$ 30 degrees either side of the satellite ground track. When this high resolution pointable system is used in conjunction with the thematic mapper, whose images are fixed and centered on the sub-orbital ground track, a number of previously unobtainable objectives may be realized. However, to maximize the data acquisition of these two sensors, it is necessary to anticipate and plan HRPI pointing maneuvers in advance of actual orbital EOS overflights.

The need for a realistic set of earth resources collection requirements to test and maximize the data gathering capabilities of the EOS remote sensor systems is the prime objective of this study. The collection requirements will be derived from established user requirements. In order to confine and bound the requirements study, some baseline assumptions were established. These are:

- Image acquisition is confined to the contiguous United States.

- The fundamental data users are select participating federal agencies.
- The acquired data will be applied to generating information necessary or in support of existing federal agency charters.
- The most pressing or desired federal agency earth resources data requirements have been defined, suggested, or implied in current available literature.

In defining specific subjects and categories selected for imaging, no attempt was made to confirm that specific observables could be or could not be used to identify specific resources. For example, if wheat has been successfully identified in multispectral image research projects, then it is assumed that wheat can be identified in EOS images and to a success degree that is acceptable to the ultimate user agency. This same assumption is used for all selected categories with no implication concerning success criteria or observable phenomena validity.

A number of "User Requirements Studies" were used as baseline data to arrive at the final collection requirements shown on the maps, charts and matrices in the body of this report. Most notably used were:

- "Advanced Scanners and Imaging Systems for Earth Observations"
- "Earth Observatory Satellite Mission Review Group"
- "Definition of the Total Earth Resources System for the Shuttle Era"
- "Office of Applications Earth Resources Program Plan"
- "A Study to Evaluate the Economics, Environmental and Social Costs and Benefits of Future Earth Resources Survey Satellite Systems"
- "Symposium on Significant Results Obtained from the Earth Resources Technology Satellite"
- "Fourth Annual Earth Resources Program Review"

Additional supporting data from the Department of Interior and the Department of Agriculture were used extensively.

2.0 SUMMARY AND CONCLUSIONS

It is necessary to generate a representative set of collection requirements to realistically study the expected accomplishment of an EOS satellite. The collection requirements are oriented toward the satellite image selection process and include all the user requirements. This was accomplished by reviewing the stated and implied information needs of federal agencies participating in the NASA Earth Observation Program. Current open publications were used as source material, with the prime document being "Definition of the Total Earth Resources System for the Shuttle Era (TERSSE)."

A list of candidate user requirements was submitted to engineering selection and study constraint filters as follows:

- o Requirements for data have national importance
- o Data can be obtained by electromagnetic remote sensor instruments
- o Fall within study constraint guidelines
- o Requirements are compatible with existing EOS mission configuration

Those user requirements that survived the above filters were subdivided into classes (disciplines), sub-classes (discipline element), resource (specific type) and categories (data and measurements to be obtained). The resulting user requirements were grouped into specific collection categories by using the most stringent time and area specifications. These resource categories were geographically located using the National Atlas. Selected areas and sites were then bounded by polygons, and the area inside the polygons was then grided (20 n.m. x 20 n.m.) to be compatible with minimum HRPI image dimensions. In this manner the entire U.S. was separated into cell/category combinations for generation of a site/requirement definition listing. The final listing was checked for accuracy and completeness by computer regeneration of the original polygons.

Finally, a complete set of matrices showing the interrelationship between collection categories and information specifications was derived.

The resultant study identified the following information classes:

Agronomy
Forestry
Geography
Geology
Hydrology
Coastal Zone
Environmental Quality
Oceanography

The last two classes were not defined in terms of their area polygons since they are not candidates for the EOS-A mission; however, their collection requirements were studied. One hundred and eleven (111) specific data collection categories were identified from the first six classes.

The EOS earth resources data collection requirements generated for this study are very heavily oriented toward applications. However, the combination of cells and categories indicate that sufficient data should be gathered to satisfy most experiments and investigators operating on a national scale. In assembling the data needs for participating federal agencies, it was found that a number of specialized requirements could be satisfied by using the most stringent repeat coverage and resolution specification. When this was combined with redundant temporal, spatial, and spectral coverage for the same or included areas, but for different information purposes, the resultant list of data acquisition needs was greatly reduced.

Some of the specific sensor characteristics that may affect the user's requirements require further study. The sensor sun angle limitation for usable data acquisition for specific categories is a prime example. This requirement should be further defined.

The results of this study should be discussed with the user agencies to determine if type of **the coverage required by the identified** collection

category requirements will satisfy their data needs. Certain categories requiring a large amount of data in a short period should be specifically reviewed to determine if these requirements are realistic for the EOS system.

3.0 USER AGENCY REQUIREMENTS DEFINITION

The two instruments proposed for inclusion on the EOS, the HRPI and TM, are typical of most remote sensing devices used to detect and record reflected and emitted electromagnetic energy. The output of both instruments will be multispectral images that contain data concerning the spectral, spatial and temporal character of many earth resources. The conversion of this image data to valuable information has a great dependency on the specific use to which the information is to be applied. For example, the data contained in a multispectral image may contain information of value to both agronomy and geology. By proper and discreet selection of observable phenomena, the particular information needs of both disciplines may be satisfied. This implies that there are different sets of observable phenomena that satisfy specific defined requirements and further that requirements may be either discipline oriented or oriented toward the accomplishment of specific organizational charters, such as those assigned to specific federal government agencies.

This requirements analysis, while carrying major discipline heading in agronomy, geology, hydrology, geography and forestry, is directed more toward establishment of observable requirements to satisfy or aid in the satisfaction of specific government agency charters. This basic background and assumptive character leads to the question "What are the observables that may be applied to satisfy or aid federal government agencies in meeting earth resource information charters?".

3.1 OBSERVABLES

There are basically two classes of "observable" electromagnetic phenomena; those associated with the instruments and those associated with the resource being observed. The observables in each class, the instrument and the resource, are contained in three fundamental subclasses: spectral, spatial and temporal.

3.1.1 Spatial

The spatial characteristics of the instruments are contained in instrument design specifications, and are directly related to what the

ultimate "users" wish to observe. The spatial character of the HRPI and TM were basically established by the EOS Mission Review Group (EOSMRG). The HRPI instantaneous field-of-view (pixel) has been established as about 10 meters when looking vertically downward. The swath width has been established as 48 kilometers (25.9 n.m.). These two parameters establish the instrument "spatial" character, when used in conjunction with the forward motion of the spacecraft. These same two parameters for the Thematic Mapper are 30 meters and 185 kilometers ($\approx$100 n.m.) respectively.

The spatial parameters from a resource point of view are much more difficult to define. Certainly the national geographic distribution of a particular resource is a desirable spatial parameter. The next spatial "level" or "strata" is the distribution density within the bounding resources geographic limits. At this level the size and shapes of the surface expressions of individual resources become important. Finally, the spatial quality, quantity and specific occupational character of a resource becomes an important element of data to information conversion. Another way of expressing these classes of space or area occupation is to bound each by terms such as macro, meso and micro, where macro-space implies large regional areas containing a resource, meso-space implies density distribution of a resource within the macro regional boundaries, and micro-space implies the spatial character of an individual resource unit, i.e., an individual wheat field.

This study used the macro and meso scale features of individual resources as the prime location features. Hence, most resource spatial locations are represented by bounded geographic areas, within each of the regional areas of resource potential based on highest density concentrations. This system resulted in the identification of specific polygonal areas or individual sites for each selected resource. These polygons were plotted on 1:7,500,000 Albers equal area projection maps, which corresponds to the most common projection used in the National Atlas.

The micro-space features were used to determine the resolution requirements for the resource and category. These features were sized to obtain the required information to identify and determine the state of the resource.

3.1.2 Spectral

Spectral observables of the proposed instruments are also a function of design specifications. Both the Goddard study (EOSMRG) and the study performed by the working group on Advanced Scanners and Imaging Systems for Earth Observations agree that the greatest user agency requirements exist in the optical region of the electromagnetic spectrum, with a sufficient number of requirements in the infrared region to justify obtaining data to about 14 microns (thermal IR). Therefore, the baseline spectral specifications of the HRPI and TM were selected to reflect these preferences. Present individual channel selections are:

Thematic Mapper (TM)		High Resolution Pointable Imager (HRPI)	
Channel	Spectral Band	Channel	Spectral Band
1	0.5-0.6 μm	1	0.5-0.6 μm
2	0.6-0.7	2	0.6-0.7
3	0.7-0.8	3	0.7-0.8
4	0.8-1.1	4	0.8-1.1
5	1.55-1.75		
6	2.1-2.35		
7	10.4-12.6		

Since the first four channels of the TM and all four channels of the HRPI correspond exactly to the MSS system used on the ERTS, it was assumed that resource spectral response information that had some degree of success, in terms of satisfying spectral requirements of federal agency users, would be successful in fulfilling EOS mission requirements. Certainly individual resources, such as wheat, iron and coal, have individual spectral characteristics that belong exclusively to the individual resource. However, no attempt was made to identify or examine the specific spectral content of resources selected for inclusion in this study. If some experimental success was achieved by spectral analysis of ERTS data or by multispectral analysis of data gathered by the NASA Remote Sensor Aircraft, then the resource was considered as a candidate for inclusion.

A number of requirements studies have been performed which relate specific spectral bands to the number of "users" desiring them and while these results were examined to determine spectral regions for specific resource measurements, they were not a prime consideration. The main consideration was, does the specific resource category require data in a particular spectral region and which sensor can best satisfy this requirement. For example, only the TM can satisfy requirements for thermal IR information.

3.1.3 Temporal

Temporal or time functions associated with the HRPI and TM, as instruments, are related to the dwell time that internal detectors have to view a pixel. This relates back to both instrument spectral response and spatial resolution. If the dwell time is relatively long, then the spectral responsiveness will probably be high and the resolution will suffer due to smear. These instrument time parameters are not germane to the user requirements analysis, and were not considered.

The temporal character of the resource to be observed is of prime importance and is of major importance to requirement analysis. Almost all resource observables change as a function of time, some more rapidly than others. In addition, these temporal changes may also be related to geographic positions and annual seasonal features. For example, winter wheat not only changes its observable characteristics with time, but observable remote sensor characteristics obtained in the same time frame are different due to geographic location. This is primarily due to the fact that different geographic regions have different planting and harvesting seasons. Also, many resources have very specific time windows for observations of value, and observation outside these time windows are of little value. For example, July observations concerning snow distribution in Nevada are of no fundamental importance.

Geographic temporal factors of all the selected resource categories were considered, as well as the "time windows" when observations would be of greatest value. The rate of change of observables essentially establishes the period of time between repeat measurements of the same resources. In this study the resource repeat coverage was

assumed to be evenly distributed over "time windows." However, in examining detailed requirements and experiment results from earth resources space observations, it is apparent that greatest applications success may be achieved by intensifying repeat coverage during specific time periods and relaxing repeat requirements during others. This may result in a better overall accomplishment factor for the EOS resource measurements program.

3.2 IDENTIFICATION OF CATEGORIES

3.2.1 Approach

The most difficult problem associated with this EOS User Requirements Study was the development of satisfactory and realistic category selection criteria. This was finally accomplished by development of a serial filtering system graphically shown in Figure 1.

The original candidate list was derived by an extensive literature search of studies associated with the NASA Earth Observation Program. While most user requirements were already listed under some discipline heading, many were carried as individual experiments (P.I. Studies) or desires defined by the academic and commercial communities. These additional requirements were assigned to an appropriate discipline class if a federal agency charter also had the same or similar requirements.

These classes were compared with those generated in the study titled "Definition of the Total Earth Resources System for the Shuttle Era," and resulted in the candidate list given in Table 1.

The assembly and comparison of the two sources was rather straightforward and yielded to specific breakdown into classes, subclasses, resources and categories discussed later. Application of the various filters to arrive at the final list was done primarily by using best engineering judgement. Some of the criteria used are as follows.

3.2.2 Remote Sensor Filter

The remote sensing filter consisted, primarily, of an examination of the individual requirements categories to determine if electromagnetic phenomena has been or could be used to acquire useful data. Other factors used in the remote sensor filter were:

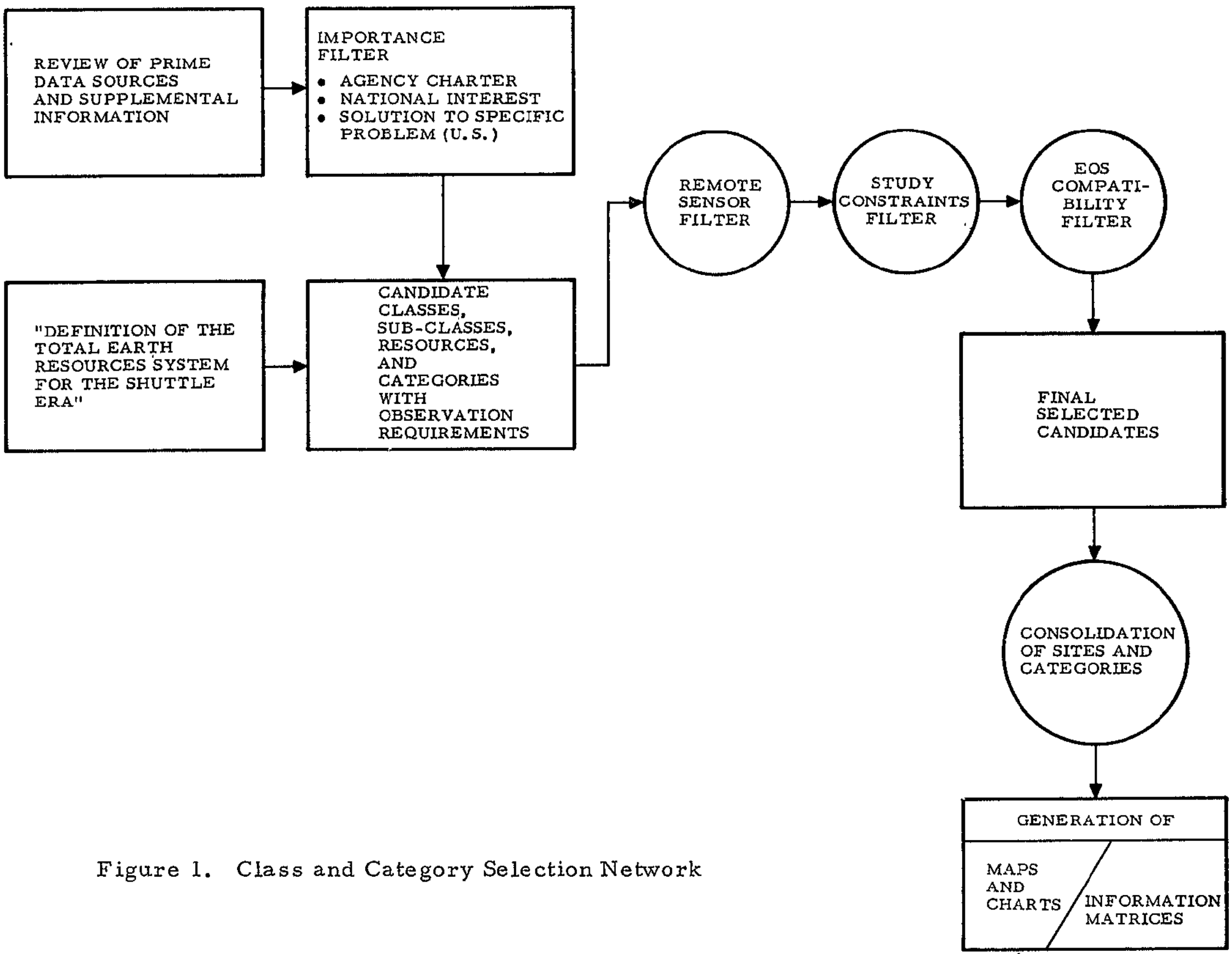


Figure 1. Class and Category Selection Network

Table 1. Candidate Earth Resources Disciplines*

1.0 Agronomy

- 1.1 Crop Inventory
- 1.2 Crop Yield - Current and Projected
- 1.3 Crop Stress
- 1.4 Weed Encroachment
- 1.5 Farming Practices
- 1.6 Soil Capability
- 1.7 Soil Moisture
- 1.8 Precipitation
- 1.9 Evapo-transpiration
- 1.10 Soil Erosion
- 1.11 Grazing Land Inventory/Supportive Capacity
- 1.12 Grazing Land Stress
- 1.13 Ecological Succession

*From G.E. TERSSE Study

Table 1. Candidate Earth Resources Disciplines (cont'd)

2.0 Environmental Quality

Air

2.1	Carbon Dioxide (CO_2)
2.2	Carbon Monoxide (CO)
2.3	Sulfur Compounds (SO_x)
2.4	Nitrogen Compounds (NO_x)
2.5	Ozone
2.6	Halogens and Their Hydrides
2.7	Peroxyacyl Nitrates (PAN's)
2.8	Flurocarbons
2.9	Other Hydrocarbons (<HC>)
2.10	Methane
2.11	Formaldehyde
2.12	Mercury, Cadmium, Lead, & Other Heavy Metals
2.13	Stratospheric Water Vapor
2.14	Heat Released from Industrial/Urban Activity
2.15	Aerosols
2.16	Radioactive Nuclides and Particles

Water

2.17	Temperature Anomalies
2.18	pH
2.19	Heavy Metals
2.20	Petroleum
2.21	Dissolved Solids
2.22	Nutrients
2.23	Dissolved Oxygen
2.24	Pesticides
2.25	Coliform Bacteria
2.26	Radioactive Nuclides
2.27	B.O.D.
2.28	Suspended Particles
2.29	Bed Load
2.30	Phytoplankton

Table 1. Candidate Earth Resources Disciplines (cont'd)

2.0 Environmental Quality (cont'd)

<u>Water</u> (cont'd)

2.31 Zooplankton and Red Tide

2.32 Algae

<u>Land</u>

2.33 Pesticide Residues in Soil

2.34 Soil Salinity

2.35 Despoiled Land

2.36 Radioactive Nuclides

2.37 Solid Waste

2.38 Urban Blight and Decay

Table 1. Candidate Earth Resources Disciplines (cont'd)

3.0 Forestry

- 3.1 Forest Inventory
- 3.2 Timber Yield
- 3.3 Forest Stress
- 3.4 Understory Inventory
- 3.5 Soil Capability
- 3.6 Precipitation
- 3.7 Surface Relief and Drainage Patterns
- 3.8 Forest Fire Assessment
- 3.9 Flammatory Conditions
- 3.10 Grasslands Inventory
- 3.11 Grasslands Stress
- 3.12 Grasslands Fire Potential

Table 1. Candidate Earth Resources Disciplines (cont'd)

4.0 Geography

Physiographic Mapping

4.1 Land Forms

4.2 Climate

4.3 Natural Vegetative Cover

4.4 Water

Social/Political/Economic Mapping

4.5 Demographic Data

4.6 Economic Data

4.7 Political and Administrative Units

Land Use Mapping

4.8 Agricultural Land

4.9 Rangeland

4.10 Forest Land

4.11 Transportation Nets

4.12 Urbanization

Cartography

4.13 Thematic Data

4.14 Planimetric Positioning Data for Information to be Mapped

4.15 Vertical Control Data for Information to be Mapped

Geodesy

4.16 Stationary Gravity Field of the Earth

4.17 Time-Varying Components of the Earth's Gravity Field, e.g., Tides, Crustal Motions

4.18 Polar Motion and Variations in the Rate of Rotation of the Earth

4.19 Precise Location of Horizontal Control Points for a Mass-Centered Coordinate System

4.20 Precise Elevation of Vertical Control Points Over the Earth's Surface, Land and Sea

Table 1. Candidate Earth Resources Disciplines (cont'd)

5.0 Geology

- 5.1 Soil Classification, Profile and Capability
- 5.2 Rock Type and Distribution
- 5.3 Location, Distribution and Capacity of Mineral Deposits
- 5.4 Tectonic Features
- 5.5 Landforms and Topography
- 5.6 Geothermal Anomalies
- 5.7 Distribution and Depth of Permafrost
- 5.8 Glaciers
- 5.9 Geological Processes
- 5.10 Geophysical Properties of the Earth
- 5.11 Continental Drift, Plate Tectonics
- 5.12 Marine Geology
- 5.13 Undersea Mineral Deposits

Table 1. Candidate Earth Resources Disciplines (cont'd)

6.0 Hydrology

- 6.1 Surface Water Inventory
- 6.2 River and Stream Data
- 6.3 Limnological Data
- 6.4 Physiography of Watersheds
- 6.5 Evaporation Rate from Water Surfaces and Bare Soil
- 6.6 Evapo-transpiration Rate of Vegetation
- 6.7 Precipitation and Surface Water Runoff
- 6.8 Soil Properties Re: Water Movement and Retention
- 6.9 Vadose Water
- 6.10 Ground Water Below Water Table
- 6.11 Aquifers
- 6.12 Glaciers
- 6.13 Wetlands

Table 1. Candidate Earth Resources Disciplines (cont'd)

7.0 Oceanography

General Oceanography

7.1 Ocean Temperature

7.2 Water Density

7.3 Salinity

7.4 Water Masses/Deep Water Masses

7.5 Ocean Circulation; Major Circulation Features

7.6 Deep Ocean Currents

7.7 Surface Wind Waves and Swell

7.8 Internal Waves (Tsunamis)

7.9 Tides

7.10 Water Composition

7.11 Sea Ice

7.12 Icebergs

7.13 Boundary Layer Exchange Processes

7.14 Shape of the Ocean Surface

7.15 Sea Floor Topography

7.16 Sea Floor Magnetic and Geothermal Anomalies

7.17 Abundance of All Organisms of Each Size in Each Trophic Level

A. Phytoplankton/Kelp/Sargassum

B. Zooplankton/Red Tide

C. Primary and Secondary Carnivores

Requirements Unique to the Coastal Zone

7.18 Near-Shore Bottom Topography and Composition; Changes With Time

7.19 Estuarine and Near-Shore Circulation Patterns

7.20 Coastal Upwelling

7.21 Surf

7.22 Storm Surges

7.23 Outfalls and River Discharges

7.24 Benthic Vegetation

7.25 Continental Shelves and Slopes

Table 1. Candidate Earth Resources Disciplines (cont'd)

7.0 Oceanography (cont'd)

Requirements Unique to the Coastal Zone (cont'd)

7.26 Dredging and Marine Construction Activities

7.27 Beach Morphology

7.28 Coastal Land Use

- Was repeat periodic geographic coverage needed to supply useful data?
- Were large geographic or widely separated areas involved such that proper coverage could be more easily obtained from space observation?
- Was measurement accessibility time constrained or perishable, such that the rapid coverage afforded from satellites might routinely gather data in a more timely mode?
- Was data gathering time-constrained, in the sense that time requirements for operational staging are generally much longer or prohibitively longer using other systems such as ground or aircraft data gathering systems?

If the answer to these questions was generally yes, then the category or resource to be surveyed was posted to the next engineering filter.

Table 2, taken from the G.E. TERSSE study, shows the results of this filtering on the data of Table 1.

3.2.3 Study Constraints Filter

The study constraints filter consisted of the bounding conditions which limited the study to available resources, both in time and manpower. These were defined as:

- The study would consider only those requirements contained within the geographic boundaries of the contiguous United States.
- Requirements that fall within the disciplines (classes) of Oceanography, Meteorology and Environmental Quality were not to be considered as elements for polygon generation.
- Some previous experimental success had been achieved, either from aircraft or spacecraft

Table 2. Potential Contribution of Remote Sensing

← AIR * WATER * LAND →

SOCIAL/POLITICAL/ECONOMIC MAPPING (Geography 5–7); CARTOGRAPHY (Geography 13–15)

DISCIPLINE/ INFO CLASS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
AGRONOMY	●	●	●	●	●	◐	◐	◐	●	●	●	●	●																									
ENVIRONMENT QUALITY	●	●	●	●	●	●	0	0	◐	0	0	0	●	●	●	◐	◐	0	0	●	0	0	0	0	0	0	0	●	0	●	●	●	0	0	●	◐	●	●
FORESTRY	●	●	●	●	0	◐	●	●	◐	●	●	◐																										
GEOGRAPHY	●	0	●	●	0	0	0	●	●	●	●	●	0	0	0	●	●	●	0	0																		
GEOLOGY	◐	◐	0	●	●	●	●	●	●	●	◐	0	◐																									
HYDROLOGY	●	◐	◐	●	●	●	◐	◐	0	0	0	●	●																									

COASTAL ZONE (Oceanography 18–28)

DISCIPLINE/ INFO CLASS #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17A	17B	17C	18	19	20	21	22	23	24	25	26	27	28
OCEANOGRAPHY	◐	0	◐	◐	◐	0	◐	0	0	◐	●	●	0	●	0	0	●	●	◐	●	●	●	◐	◐	◐	0	0	●	●	●

LEGEND: ● - SIGNIFICANT CONTRIBUTION VIA REMOTE SENSING - SOME ANCILLARY DATA REQUIRED

◐ - SIGNIFICANT ANCILLARY DATA REQUIRED BUT REMOTE SENSING IS USEFUL

0 - NO WAY (NOT FROM REMOTE SENSED DATA) - WOULD NEED A MAJOR BREAKTHROUGH FOR REMOTE SENSING TO BE USEFUL

FOLDOUT FRAME 1

FOLDOUT FRAME 2

remote sensor systems. Judgement as to the degree or validity of success was not considered.

- o High on the list of priorities of the participating agencies, as nearly as could be determined.

If candidate requirements successfully passed this filter of judgements, then the EOS filter was applied to arrive at the final list of candidates.

3.2.4 EOS Filter

The EOS filter was built around mission configurations as furnished by the Goddard Space Flight Center EOS Program Office and the TRW/EOS Program Office. The filter included the following:

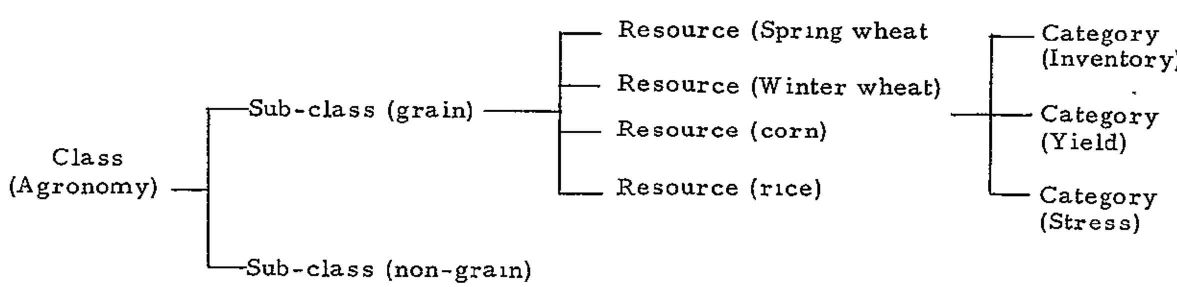
- o Data gathering could be accomplished by state-of-the-art unmanned spacecraft.
- o Data requirements compatible with instruments proposed for EOS-A (HRPI and TM).
- o Proposed mission configuration(s) would allow reasonable chance for data acquisition.
- o Satellite resources (power, data transmission, signal conditioning, etc.) are sufficient for unconstrained operations over the contiguous United States.

The final list of candidate requirements was assembled under their individual discipline heading for further division such that specific categories of observation could be defined.

3.2.5 Category Consolidation

Examination of Table 1 shows that some candidate items fell under more than one discipline. Also, the requirements for coverage of one item would often completely satisfy the requirements for coverage of other candidate items. At the same time some of the disciplines identified in the G. E. TERSSE study were broken down finer to reflect specific resources identified as being of prime importance in the "Earth Resources Program Plan."

Each of the discipline classes were divided into sub-classes, such as grain and non-grain for agronomy and metals and energy minerals for geology. The sub-class division was rather arbitrary, but primarily selected on the basic sub-divisions and charters of participating government agencies, i.e., Fuels Division of the USGS and Statistical Reporting Service of the Department of Agriculture. The selection of individual resources such as wheat or coal was primarily based on those individual resources which appear to have been studied most intensively in past NASA Earth Resources Program elements or were confirmed as being high on agency priority lists by personal communication. Finally, specific categories were selected on the basis that each of the identified specific resources in the sub-classes had similar requirements for specific types of data. This selection process resulted in the following example breakdown:



This structure was applied to the final candidate list and is reflected in the polygons and matrices of Sections 3.3 and 3.4.

3.3 SITE AND AREA DEVELOPMENT

3.3.1 Method

Since the instrument observable characteristics were established by design, and the resource observables are defined within bounds, it then becomes necessary to locate and determine the position of specific resources geographically. With specific resource category candidates identified, maps depicting regional resources distribution were generated. This was basically accomplished by bounding the selected resource categories with enclosing polygons. The enclosing polygons were drawn around areas of maximum resource density on Albers equal area map projections. If the resource was not distributed, but occurred more as an individual point site, then the site was identified as a point cell. In a number of cases the regional aspects of resource observables or the wide separation of high density resource locations played such an important role that more than one polygon was developed.

The geographic location of the selected resources was rather straightforward. Almost all specific resources, sub-classes and class polygons were obtained from density distribution maps or other charts, contained in the National Atlas. The individual polygons were derived at the resources level such that each measurement category falls within its subject resource.

The individual classes are not geographically identified on any single map. Individual map generation begins at the sub-class level and in most cases shows all the resource levels assigned to the specific sub-class. For example, the resource levels, corn, winter wheat, spring wheat and rice are all shown on a single conterminous map of the United States in Figure 2. The specific categories are all contained within their specific resource polygons and are not individually identified.

3.3.2 Area Description

3.3.2.1 Prime Grain Crop Regions

The individual polygons for corn, winter wheat, spring wheat and rice (Figure 2) do not contain all areas which produce these specific products. However, each of the polygons surrounds those areas which

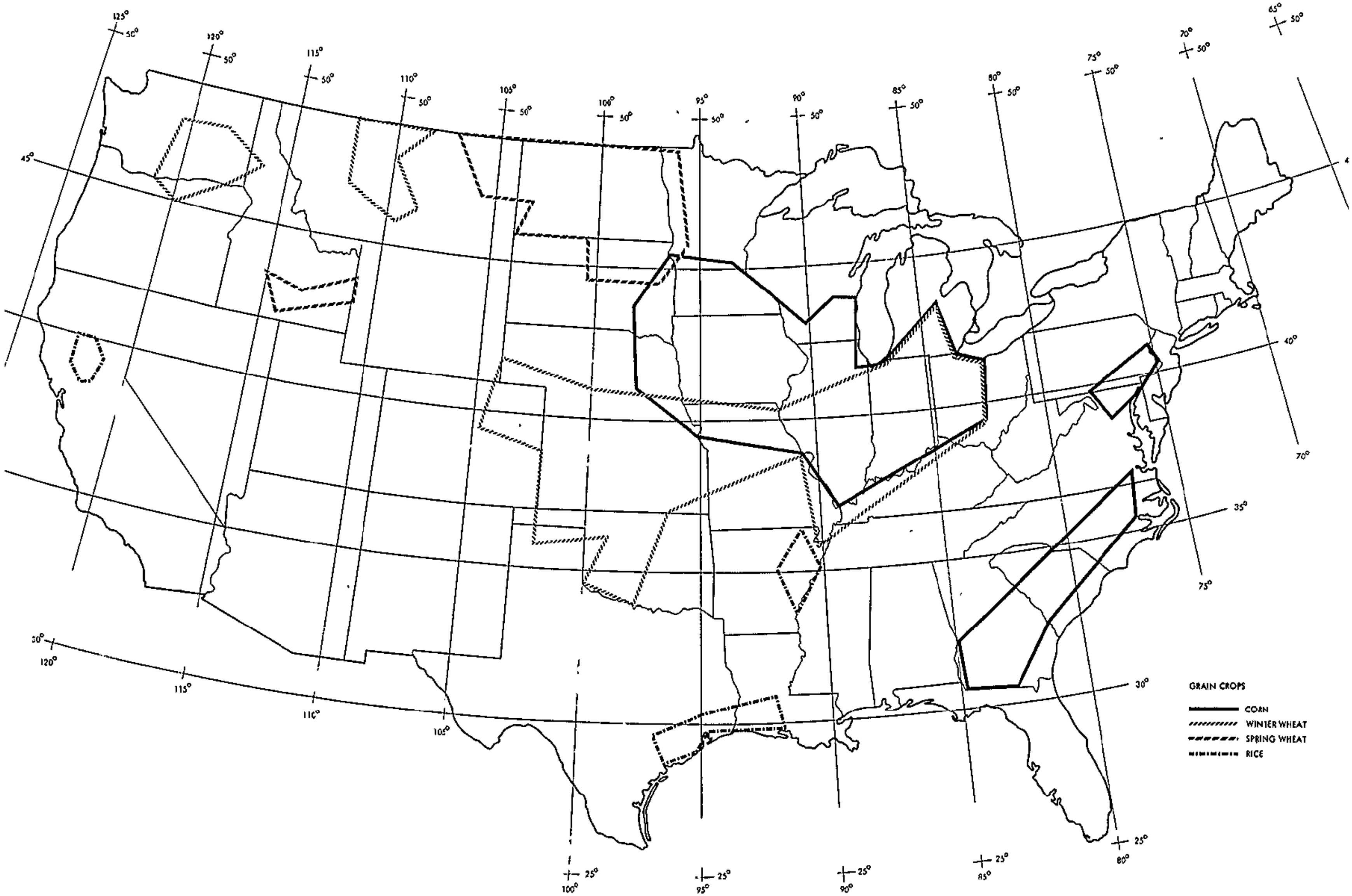


Figure 2. Prime Grain Crops Regions

are resource intensive and are visually estimated to include approximately 80% of the total acreage tilled for each of the individual resources. Corn is represented by three polygons, mostly confined to those regions east of the Mississippi River. Winter wheat is represented by three polygons, with the primary production area located in the central plains area, with two smaller regions of high intensity production in the northwestern United States. The northern-most limit of the northern polygon stops at the U. S. /Canadian border, even though winter wheat growing extends into Canada.

The growing season variations across the United States require that the polygons for each crop be grouped according to the local climate. For this reason winter wheat, corn, cotton, and citrus were split into regional categories with different time windows for data collection.

3.3.2.2 Prime Non-Grain Crop Regions

The previous discussion on Prime Grain Crop Regions; holds for the subject area also. One particular aspect of the non-grain crop polygons is rather apparent. Those resource levels selected as having the highest priority for EOS imagery, are concentrated east of the Mississippi River. Inclusion of some uniquely "Western" crop may be of value. Figure 3 shows the distribution of high density concentration of tillage for soybeans, cotton and tobacco, which are considered to be important non-grain crops, on a national scale, by the Department of Agriculture. The determination that these are the most important crops for applications systems has not been made.

3.3.2.3 Forest, Grasslands and Citrus Regions

The combination of polygons for forest, grasslands and citrus regions is based on the fact that forest and grasslands generally include areas of natural growth and citrus farming has remote sensing characteristics more closely associated with forestry than non-grain agriculture. The polygon distribution of these resources is shown in Figure 4. In the process of generating the subject polygon areas, from data contained in the National Atlas, it was noted that significant differences existed in tree and forest types based on geographic location. Therefore, polygons were selected in such a way as to separate forests with significant type

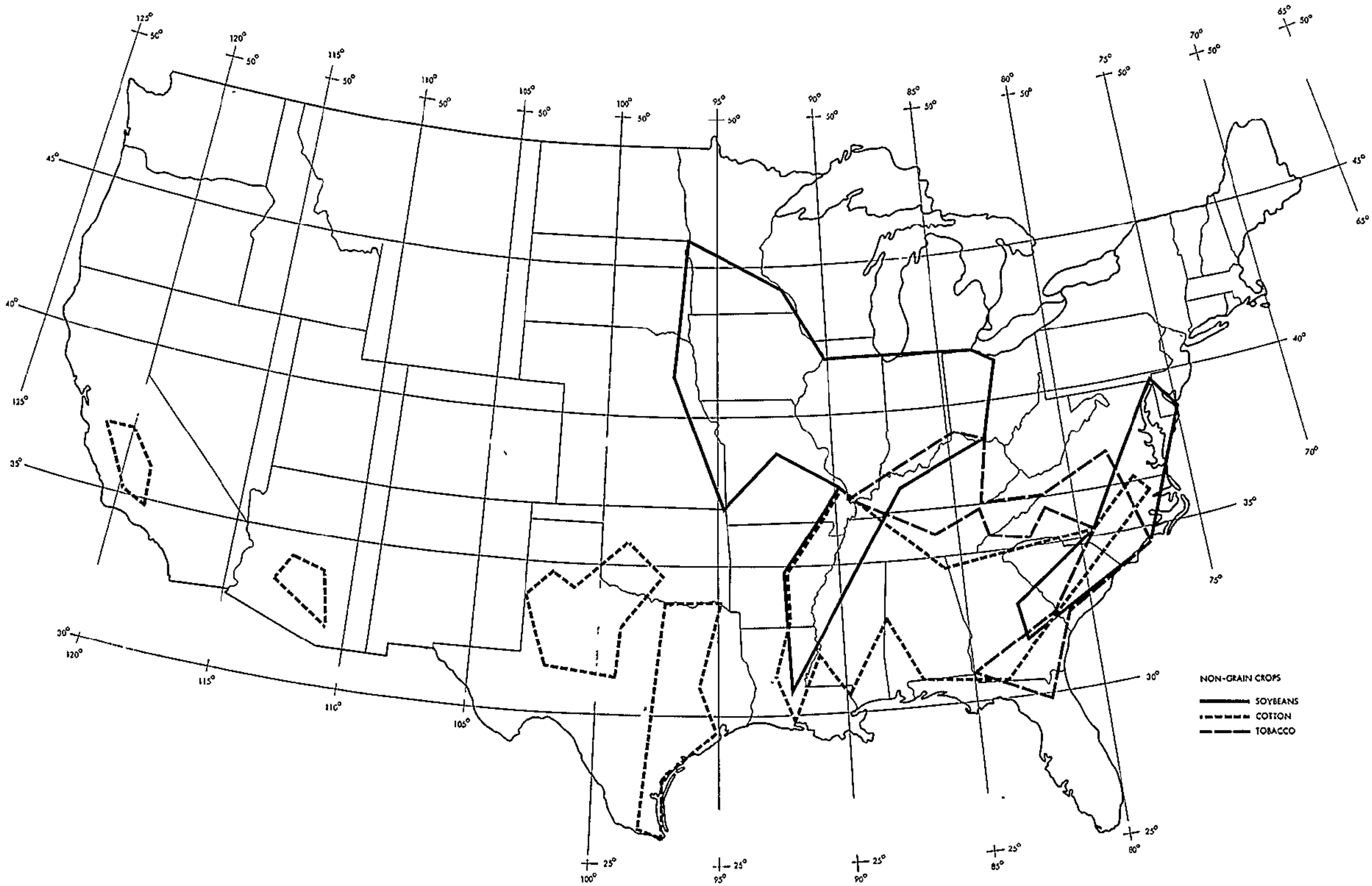


Figure 3. Prime Non-Grain Crop Regions

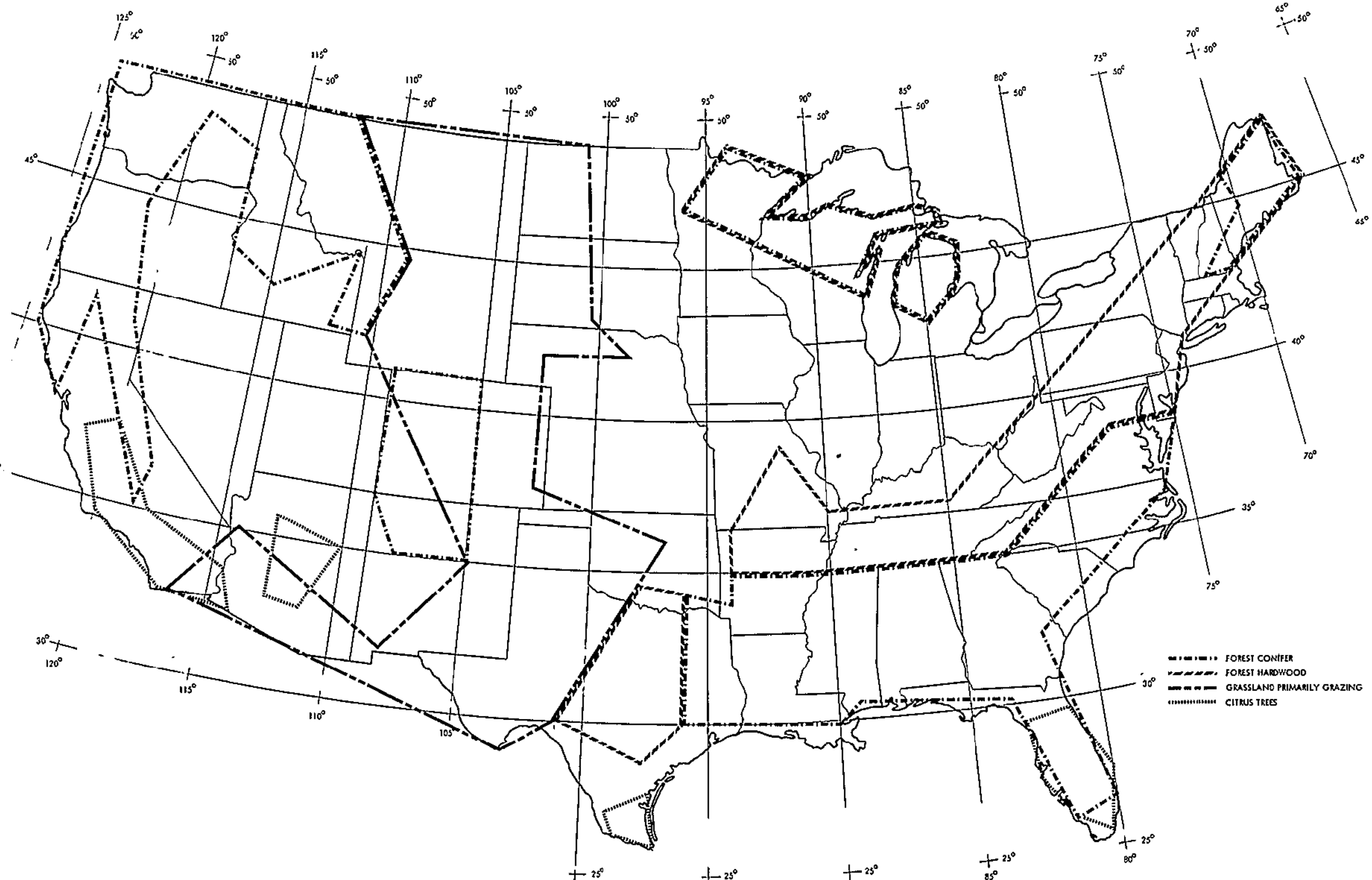


Figure 4. Forest, Grasslands, Citrus Regions

differences. The "grassland" resource polygon, which is confined to west central United States, was selected on the basis that it not only represents grasslands, but grasslands strongly associated with livestock grazing. A polygon that represented all grasslands would probably encompass the entire U. S.

3.3.2.4 Seasonal Precipitation and Snow Accumulation Regions

The Seasonal Precipitation polygons shown in Figure 5 cover the entire United States with some overlap by adjacent enclosures. While each of the polygons are shown according to season, the actual boundaries encompass an area with an expectation of more than two inches of rainfall (or water equivalent precipitation) per month. These data were extracted from the National Atlas and compared with weather bureau charts. Therefore, observations can be expected to have a high probability of precipitation encounter. In Figure 6 snow accumulation polygons are based on snowfall being the expected type precipitation during specific time periods. This also was correlated with expected ground temperatures being below the freezing point, on a seasonal basis. The snow accumulation regions does not take into consideration the type of precipitation associated with very high altitudes, such as the higher elevation in the Rocky Mountains.

3.3.2.5 Geographical Mapping Regions

The polygon divisions for geographic mapping purposes, Figure 7, were selected on the basis that each of the geographic regions contains either a USDI or USDA regional office. Various regional offices may have differing requirements for maps and charts within their area. This same division is generally compatible with geographic similarities. That is, each polygon, generally speaking, encloses an area of similar terrain, weather and population types, based on data available in the National Atlas. In addition to the large area mapping function, there is a requirement for urban and transportation mapping which is concentrated in a few pilot areas. The pilot sites are those identified by the TERSSE study which include:

San Francisco Bay
Seattle - Puget Sound

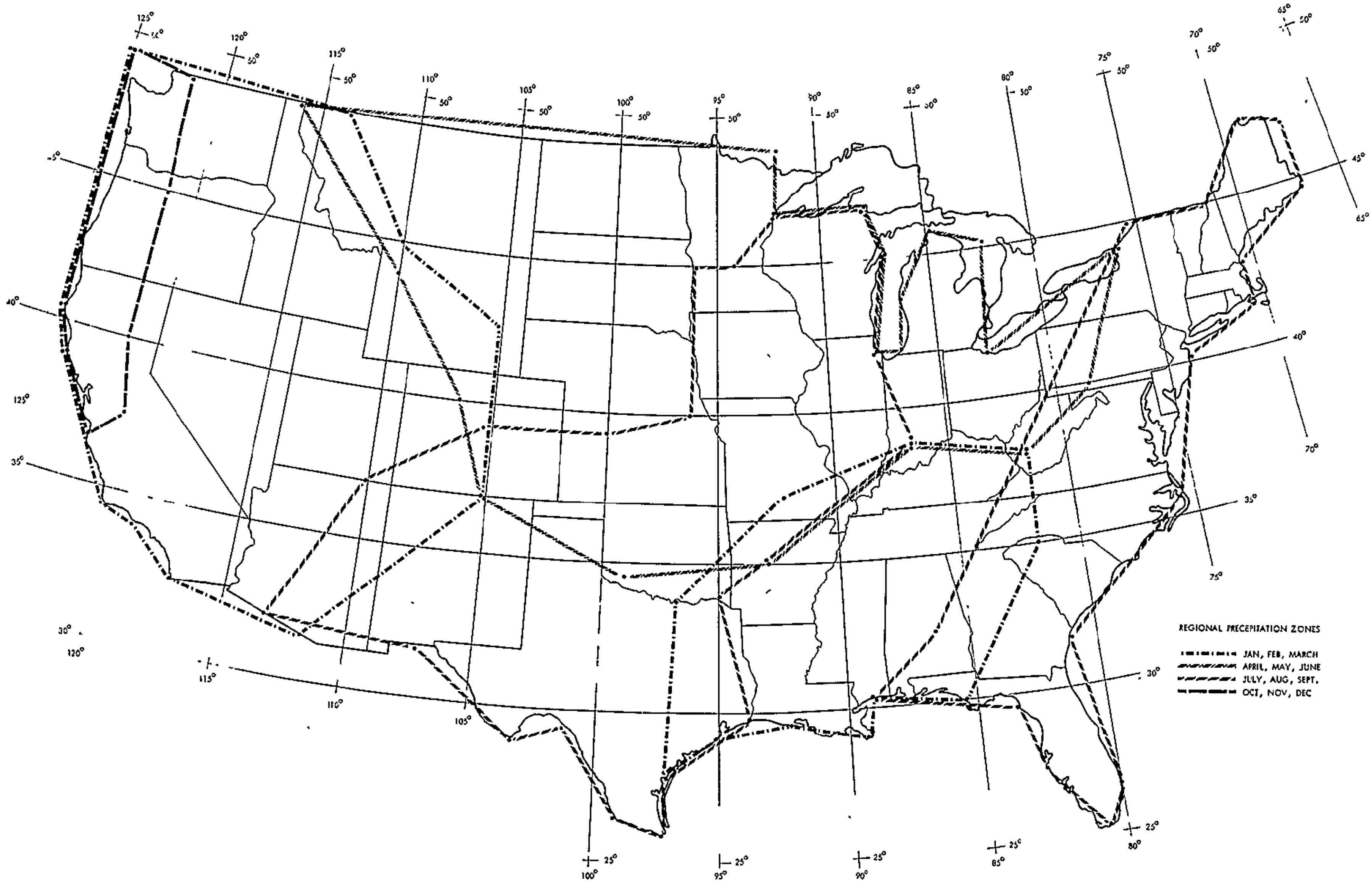


Figure 5. Seasonal Precipitation Regions

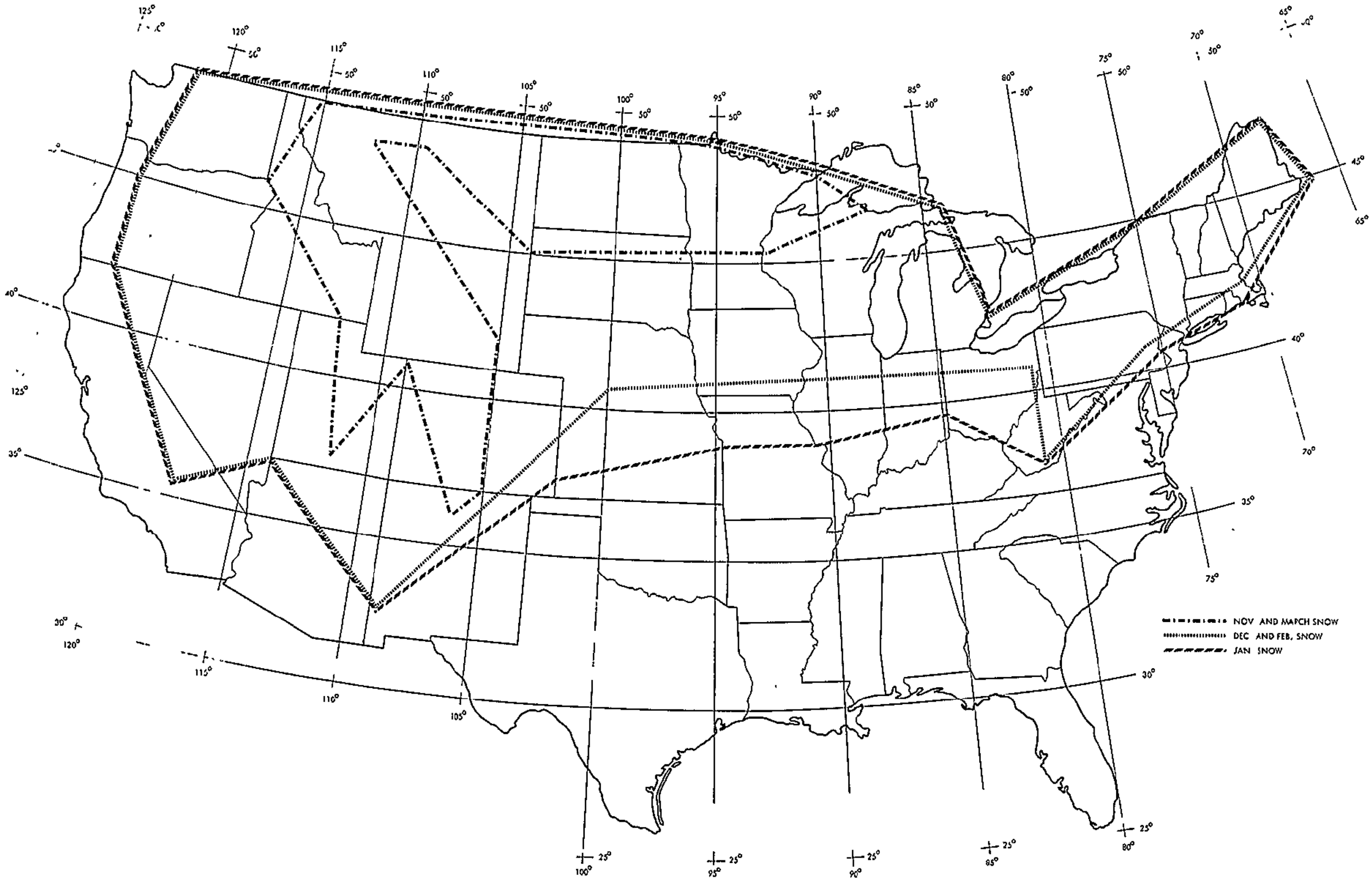


Figure 6. Snow Accumulation Regions

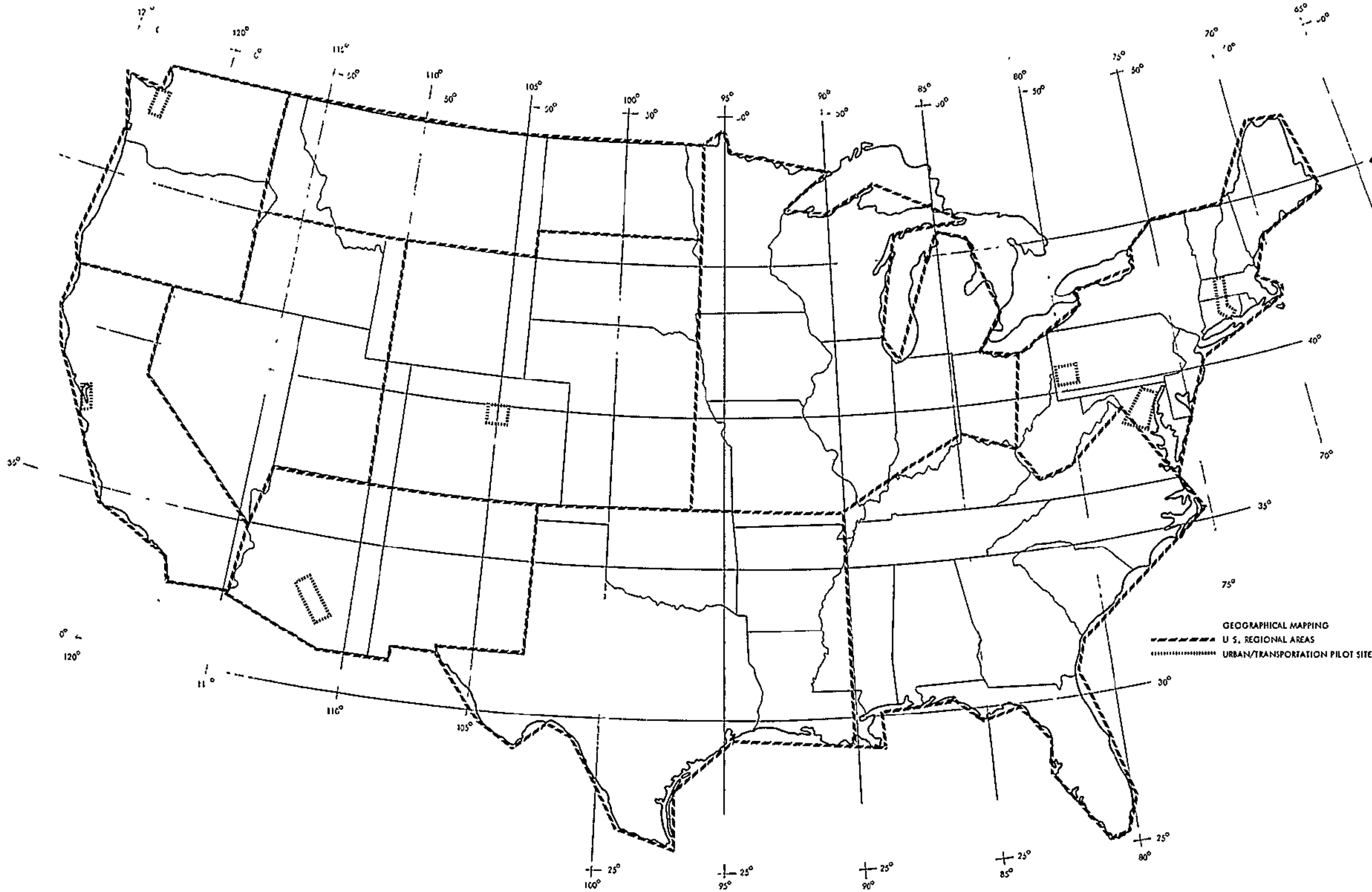


Figure 7. Geographical Mapping Regions

Phoenix - Tucson
Denver
Pittsburg
Connecticut Valley
Baltimore - Washington, D. C.

3.3.2.6 Prime Metals Regions

The prime metals regions (Figure 8) were derived from the National Atlas, which shows the regions of mining activities as functions of metal type. This was compared to the geologic map of the U. S., and the polygon was drawn to include areas of similar geologic environments; in this way, the polygons not only include the areas of exploitation but also the areas where maximum exploratory activities are probable.

The inclusion of nickel as one of the major metals may not be valid from an applications point of view, because U. S. nickel production and potential nickel areas is small in a relative sense. However, nickel is a very important metal to the U. S. manufacturing industry and gained information may be extremely significant to locating unknown deposits. From a resource applications point of view, zinc, mercury, silver or similar metals with higher U. S. production may also be significant.

3.3.2.7 Prime Energy Minerals Regions

Relatively heavy emphasis was put on these particular resources in view of the recent and continuing energy crisis. The distribution of energy mineral polygons is shown in Figure 9. Like the metals polygons, the dimensions of the energy polygons include geologically similar areas so that data for exploratory purposes will be obtained. The "uranium" region was developed to also include some of the radioactive phosphors, because these have been postulated as a potential source of energy producing materials.

Major geothermal areas shown in Figure 10 were separated from the other energy minerals because geothermal energy is not associated with specific mineral types, but is dependent on thermal character. The defined polygon areas are those containing Known Geothermal Resource Areas (KGRA's). This method was chosen because of the possibility of transfer of known information development techniques to unknown areas.

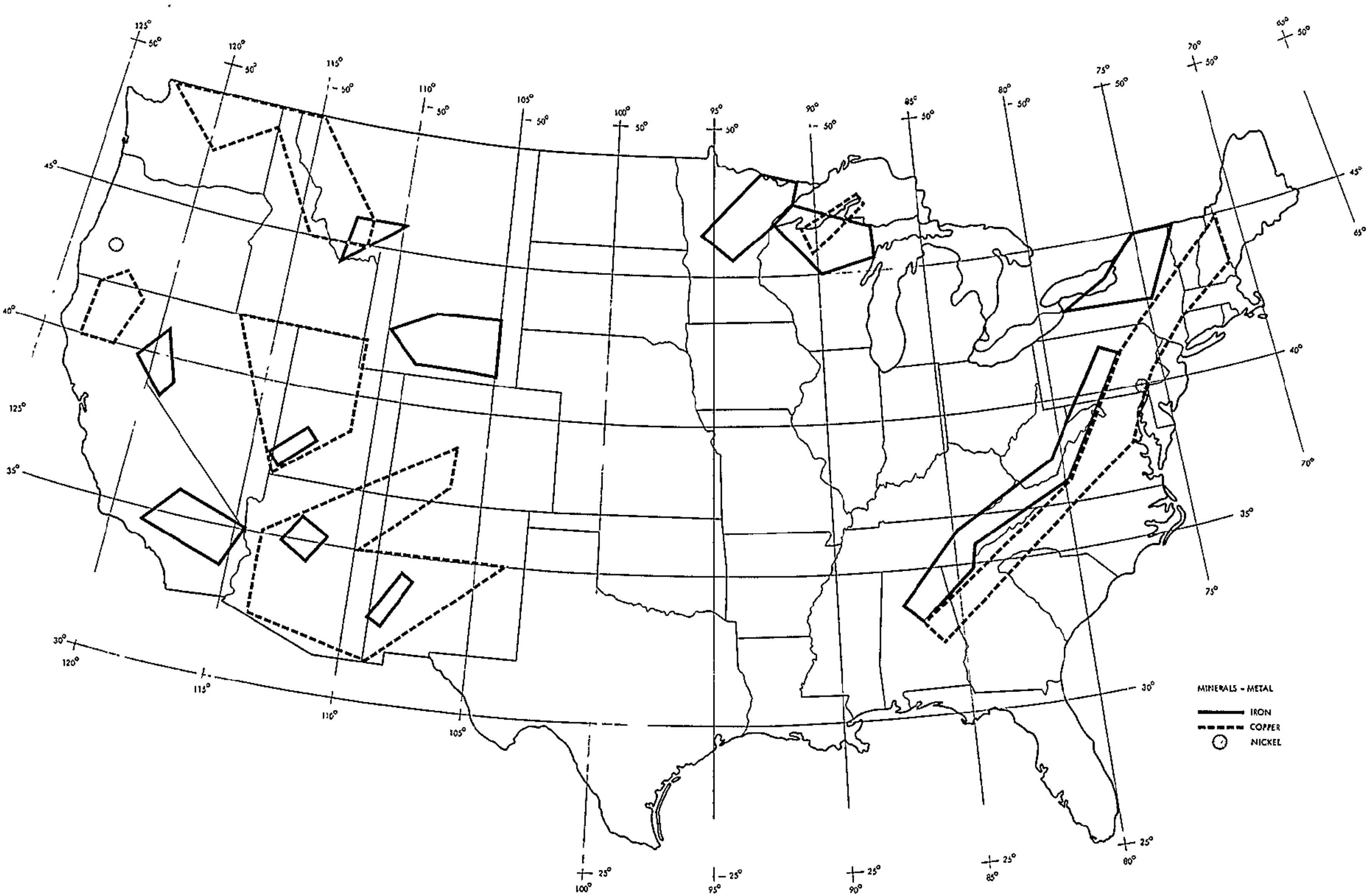


Figure 8. Prime Minerals-Metals Regions

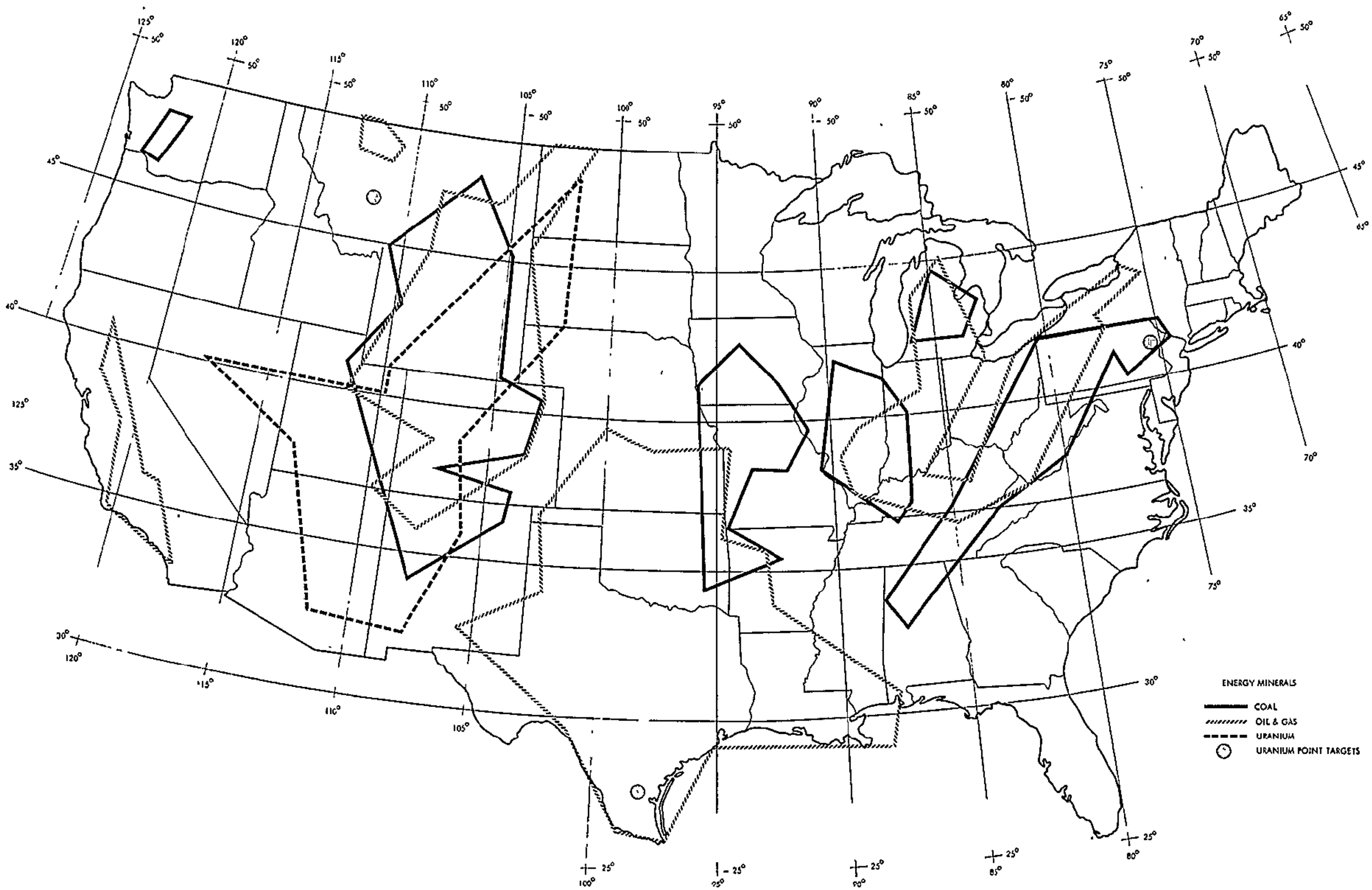


Figure 9. Prime Minerals-Energy Regions

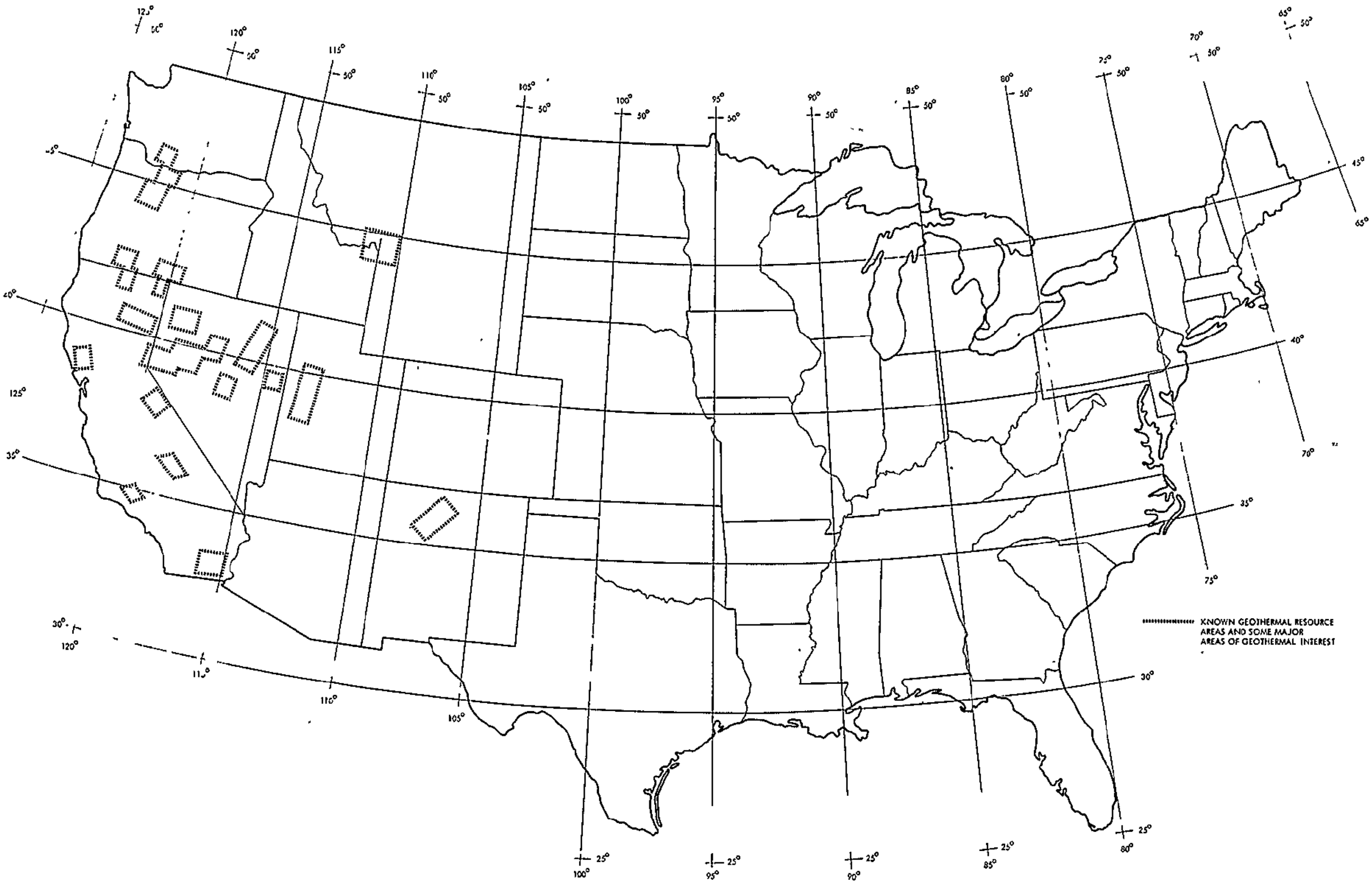


Figure 10. Major Geothermal Regions

3.3.2.8 Hydrology

The Hydrology class contains surface water, wetlands, and glaciers. Surface water requirements include a national inventory and a monitoring of major rivers, lakes, and reservoirs. Wetland regions, of the coastal type, were considered to be included with Coastal Zone Regions and are not included as measurement areas in this sub-class. Figure 11 shows the specific polygons and sites selected for this study. Each of the lakes, reservoirs and rivers were selected as being representative of particular types, rather than a complete set of specific desired inland water bodies. The requirement for national water inventory is covered by a complete mapping of the U.S. Therefore, the selected sites are representative of areas requiring intensive study. The specific chosen sites are:

- Lakes
  - Shasta
  - Mead
  - Tawakoni
  - Connersville
  - Douglas
  - Seminole
- Reservoirs
  - Sherman
  - Potholes
  - Rathbone
- Rivers
  - Columbia
  - Sacramento
  - Pecos
  - Missouri
  - Mississippi
  - Ohio
  - Hudson
  - Savannah
  - St. Johns

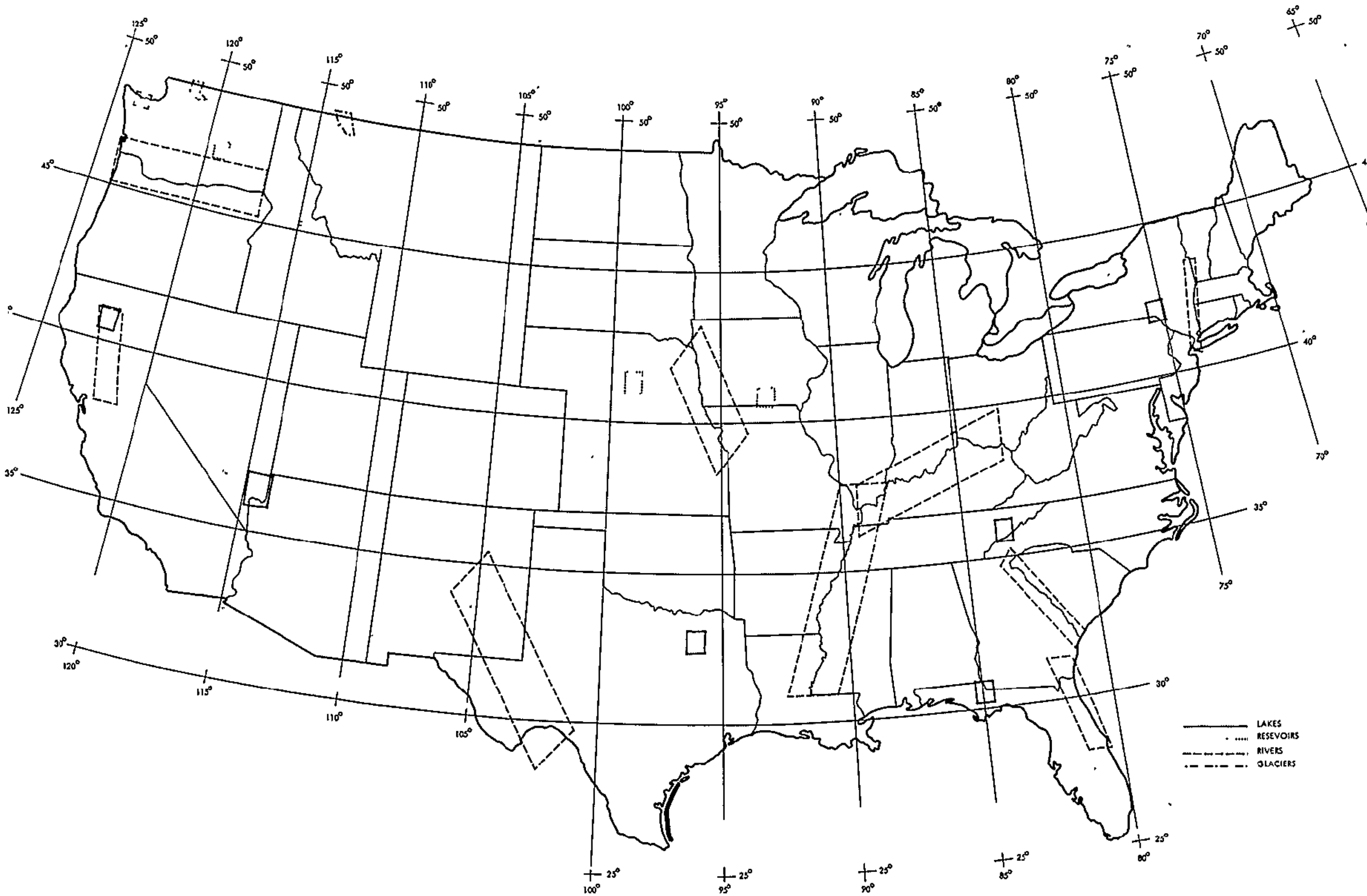


Figure 11. Hydrology Regions

The requirement for monitoring glaciers was generated by the National Park Service and consists of monitoring specific national parks. The parks chosen for this category are:

- Olympic N. P.
- North Cascades N. P.
- Glacier N. P.
- Mt. Rainier N. P.

3.3.2.9 Coastal Zone Regions

The coastal zone polygons were divided into five separate enclosures (including Great Lakes) based on major coastal zone types. Figure 12 shows the detailed selection. Within each major coastal zone type, major river mouths were selected as river discharge measurement sites, with each selection being typical of the region and associated with major watershed and river basin areas. Estuaries within the coastal zone areas were selected as typical of the region.

The Great Lakes region requires the identification and location of surface ice during the winter months that would affect commercial traffic on the lakes. Critical points were chosen as monitoring areas which included major ports and channels.

Estuaries and river mouths are areas of concentrated data requirements. Typical major estuaries were considered and they are listed below.

- Long Island Sound
- Chesapeake Bay
- Pamlico Sound
- Jacksonville, Florida
- Cape Kennedy
- Florida Everglades
- Tampa Bay
- Mobile Bay
- Mississippi Delta
- Galveston Bay
- Corpus Christi
- San Diego Bay
- San Francisco Bay
- Puget Sound

The river discharge areas are all located along the coasts. Major areas are shown and smaller areas were considered point sites (contained within the HRPI field of view) and not shown in Figure 12. The areas to be surveyed on larger rivers extend out into the ocean a considerable way to include most of the discharge plume. The rivers chosen for this study were:

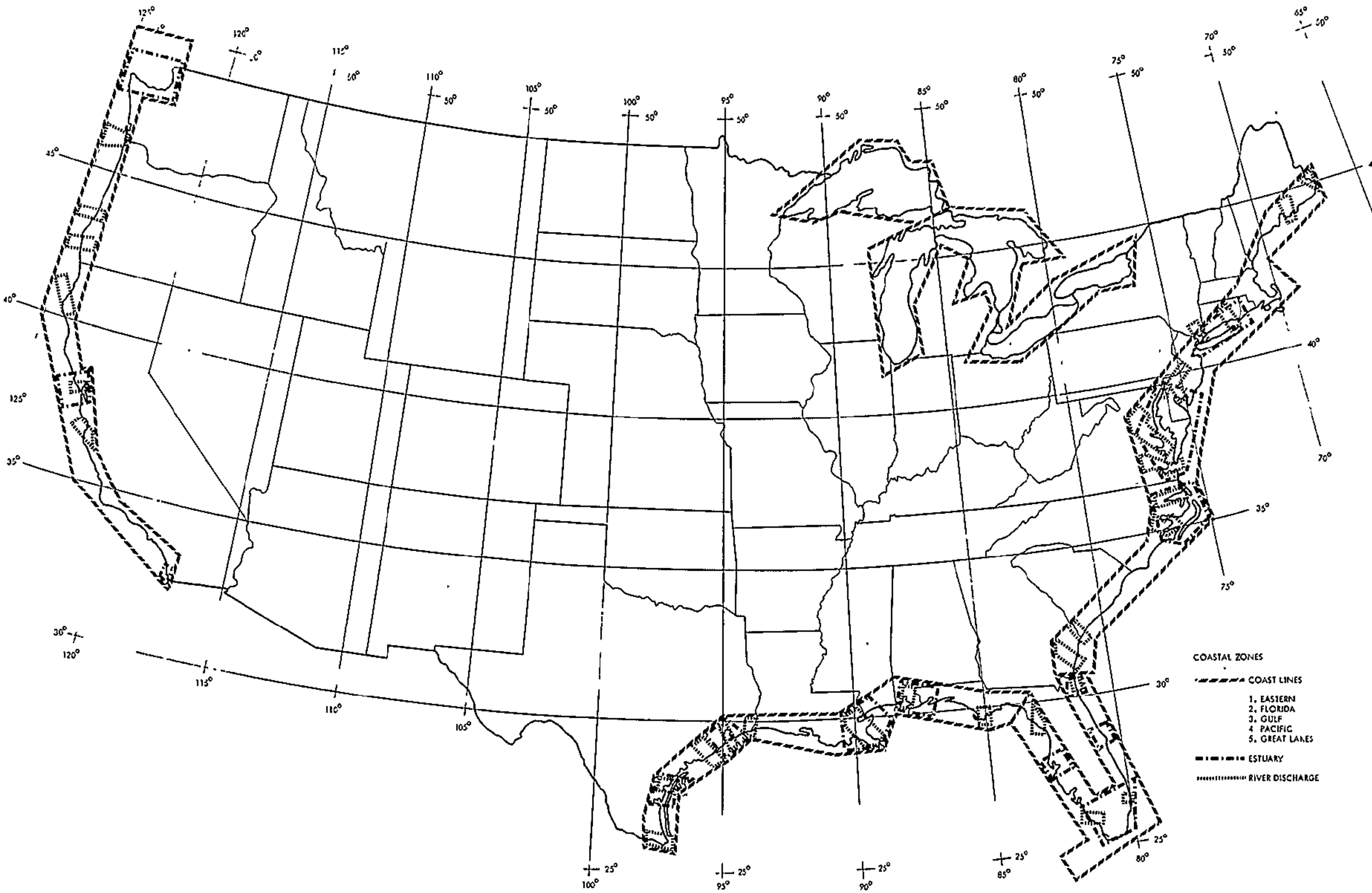


Figure 12. Coastal Zone Regions

St. Croix	Savannah	Trinity
Penobscot	Altamaha	Brazos
Connecticut	St. Johns	Nueces
Hudson	Hillsboro	Rio Grande
Delaware	Caloosahatchee	Salinas
Susquehanna	Suwannee	Sacramento
Potomac	Apalachicola	Eel
James	Mobile	Rogue
Chowan	Mississippi	Umpqua
Pamlico	Sabine	Columbia

3.3.3 Polygon, Cell and Site Checking System

The express purpose of developing the previously discussed polygon, cell and site maps was to determine the location and distribution of the collection requirement categories. Therefore, a TRW program for graphically displaying areas in the United States was used for validation, with the generated category locations as the driver. The system used the same projection and scale as was used as a base to outline the original polygons (Albers Equal-Area Projection: Scale of 1:7,500,00).

This program was assembled using available TRW software library programs and routines for plotting of cartographic and map-related data, so as to be able to quickly checkplot and validate the polygons by visual comparison of the computer plotted polygon maps with the original hand-drafted polygon maps. The program itself is in FORTRAN (TRW/TSS/CDC) and performs the following functional sequence of activities:

1) Based on the specified map projection and map definition parameters, (map scale, reference parallels, and map center), the program internally generates the coordinate transformation between geodetic (latitude/longitude) coordinates and Cartesian (X/Y) CalComp plotter coordinates.

2) Using the above coordinate transformation and the specified map extent and grid spacing, the program draws the desired latitude/longitude grid.

3) Using an internally contained map data base and the coordinate transformation developed in 1), the national and state boundaries may then be plotted. It should be pointed out that this internally contained map data base is very crude, generally containing points with a resolution of only 0.5 degrees, and was designed primarily for continental and global scale map displays on a CRT type terminal device.

4) The program then reads the designated polygon definition, one polygon at a time, converts latitude and longitude from degrees, minutes and seconds to degrees and decimal fractions of a degree, and reformats the data so it can be plotted using one of the available cartographic data plotting routines.

Examples of the checking system are shown in Figure 13, with the U.S. base map supressed.

3.4 REQUIREMENTS MATRIX GENERATION

The collection requirements for the consolidated categories are listed in Tables 4-10. These categories and requirements are based heavily on the data requirements of the major federal organizations as identified by the G. E. TERSSE study. Some of the candidate items listed in that study as being amenable to remote sensing were not reflected in the requirements of the major federal organizations. Unless other available information indicated a prime desire for this information, the item was dropped from consideration. Where gaps appeared in the desired collection requirements, they were filled with information obtained from other sources listed in the Bibliography. This data was then organized into a matrix with the collection categories listed as row headings and the collection requirements listed as column headings.

3.4.1 Matrix Description

The following paragraphs correspond to the headings used for the matrix columns. Each paragraph gives a description of what information is contained in the column and an indication of the prime sources.

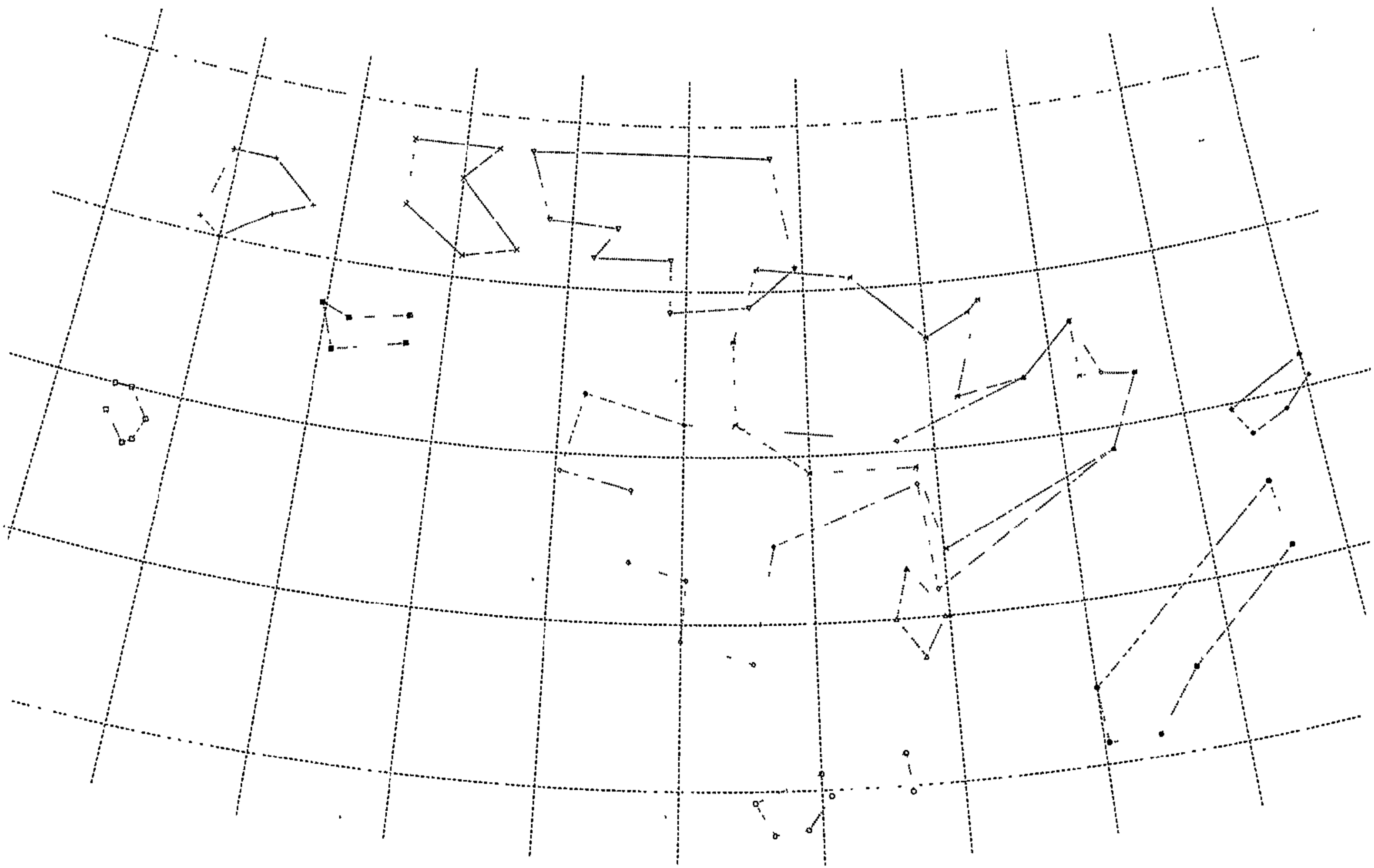


Figure 13. Computer Polygon Check, Grain Crops

3.4.1.1 Collection Category

The collection categories identified in the first column are the result of the filtering and consolidation process described earlier. The organization of the column gives the sub-class, resource, and category.

3.4.1.2 Cat. Number

The category number is a number assigned for identification.

3.4.1.3 Instrument

This column identifies the sensor to be used in satisfaction of the requirements for each category. A given category may require the Thematic Mapper, the HRPI, or may be satisfied by either sensor. The determination of which choice is made is dependent primarily on the resolution and spectral requirements. If conflicts arise between these requirements such that neither sensor can totally satisfy the requirement, the dominant requirement (resolution or spectral coverage) is used if useful data can be obtained with the applicable instrument.

3.4.1.4 Coverage Repeat

This column gives the repeat cycle period required for coverage of each category. The cycle period is broken down into any number of hours, days, weeks, months, or years. A space is also provided for a specific number of observations of a site without a rigid time constraint such as one time only or three times during a construction project. The primary source for the repeat coverage data was the G.E. TERSSE study. The repeat cycle identified is generally the most stringent requirement quoted for that category and the satisfaction of that requirement will also satisfy less severe requirements.

3.4.1.5 Observation Season

The observation season reflects the seasonal character of some of the requirements. The seasons generally correspond to the seasons of growth for crops or forest, seasons of occurrence of certain phenomena such as snow or ice, or reflect the need for coverage at anytime without snow cover. The data for this column came from several sources such as "Usual Planting and Harvesting Dates" Agriculture Handbook No. 283.

3.4.1.6 Approx. Area

The area identified in this column is the area in square kilometers that is required to satisfy each category. If the requirement is 3% coverage of the Eastern conifer forests, then the area represents 3% of the Eastern conifer area enclosed within the designated polygon.

3.4.1.7 Area Coverage

The area coverage column gives the percentage of the total category area or sites that must be imaged under cloud free conditions during each coverage repeat cycle. This is one of the prime factors in determining the amount of data that the satellite must return to satisfy the category requirements. Data on the percentage coverage required is hard to find; however, data was available for the crops and forest lands where extensive work has gone into the establishment of statistical models for estimating yield. Other data was derived from estimating the amount of active area within a category that required repetitive monitoring versus the total inventory area, e.g., active mining versus total potential coal fields. Still other data is the best engineering guess that could be made from the available sources and verbal communications.

3.4.1.8 Resolution

The resolution column gives both the range of resolution values, in meters, desired by a number of users and the specific resolution value chosen for this study. This chosen value reflects both the user requirements and the instrument capability. Some data was available which gave the distribution of resolution requirement for specific data from a number of users. This data generally had several peaks at the most desirable resolution levels. The data in this column generally reflects the most stringent resolution value for which useful information can be obtained by the EOS sensors.

3.4.1.9 Information Grid Size

The information grid size is an indication of the detail with which the output product must be delivered to the user, whether that be in a digital or analog form. In digital form, it would represent the grid size in the stored output data base. On a map, it would represent the minimum size area displayed as uniform in nature. This does not represent a

resolution requirement but a reporting requirement. For example, some crop yield requirements have an information grid size of a county whereas the resolution required to obtain the yield data is only a few meters. Other data is desired on a unit size as small as 50 x 50 meters. The information grid size shown generally reflects the most stringent requirement for the category and as such tends to be biased toward the lower values. These data were directly extracted from the TERSSE preliminary report.

3.4.1.10 <u>Spectral Range</u>

The spectral range column is divided into bands with unique characteristics. The visible bands are included in the .5-.8 μ range with the near IR in the .8-1.1 μ range. The TM and HRPI each have a total of four separate bands in these ranges. The TM has an additional two bands in the intermediate IR range - 1.5-2.3 μ and a band in the thermal range - 10-13 μ.

The solid bars across the columns indicate the most desirable spectral ranges with the dashed lines giving additional ranges that can supply some useful information.

3.4.1.11 <u>Priority Assignment</u>

A priority level was assigned to each category on a scale of 1-10 with the higher number having the higher priority. These priority levels were based on engineering judgement and were developed solely by TRW. Maximum priority was reserved for emergency situations such as assessing conditions during a forest fire, low priority levels were used for those categories that had long repeat cycles or were not critical in terms of data return.

3.4.1.12 <u>G.E. Discipline Reference</u>

This column references the disciplines identified by General Electric in the TERSSE study. The numbers in the column correspond to the numbers in Table 1. The disciplines listed in this column are the primary disciplines that are satisfied by each category.

3.4.1.13 <u>Gov't Agency (G.E. Source)</u>

This column identifies the government agencies that gave rise to the requirements or have need for the data. These agencies with their

numerical designation are given in Table 3. This data was obtained from the General Electric TERSSE study which identifies the tasks of each government agency as they relate to the various earth resources disciplines.

3.4.1.14 Remarks and Special Requirements

This column is reserved for the addition of special requirements not covered by the previous columns and notes explaining the source and significance of some of the requirements.

3.4.2 Matrix Discussion

3.4.2.1 Agronomy

The class of Agronomy contains cropland status, soil condition, precipitation, and grazing land status. The cropland categories were broken down into the prime use areas suggested in the ERPO Program Plan. The matrices for these crops are given in Tables 4 and 5. Each identified crop contains an inventory, yield, and stress category. The inventory requires that 80% of each crop's area be imaged every three months during the growing season to determine the acreage under cultivation for each crop. The approximate area given is the total polygon area which is approximately 80% of the crop area as indicated previously. The citrus area is inventoried only once a year due to the more permanent nature of the crop. The combination of all the crop inventories covers a large portion of U. S. farmland so this data is useful for observation of farming practices and further research in the application of space acquired data to agronomy.

The Department of Agriculture, Statistical Reporting Service, has 17,000 sampling units (one square mile each) scattered over the United States. While these sampling units are used for all crops by all divisions within the Department of Agriculture, specific units have prime designators, based on crop type. For example, about 750 sample units are classed as "wheat." The distribution of designated sample units is based on the density distribution of specific crops. For example, Indiana is highly wheat intensive and therefore has more wheat sample units than the state of Texas. The sample units are not static and are generally moved (relocated) every 2 to 4 years. Since the sample units are used to predict "yield" by very carefully analyzing very small crop

Table 3. Government User Agencies

1) USDI

   1.1 Geological Survey
   1.2 National Park Service
   1.3 Bureau of Sport Fisheries and Wildlife
   1.4 Bureau of Reclamation
   1.5 Bureau of Land Management
   1.6 Bureau of Mines
   1.7 Bureau of Indian Affairs

2) USDA

   2.1 Forest Service
   2.2 Soil Conservation Service
   2.3 Statistical Reporting Service
   2.4 Animal and Plant Health Inspection Service
   2.5 Economic Research Service
   2.6 Agriculture Stabilization and Conservation Service
   2.7 Agriculture Research Service

3) EPA

4) USDC

   4.1 National Oceanic and Atmospheric Administration

5) DOD

   5.1 U.S. Army Corps of Engineers (Civil Works)

Table 4. Agronomy Matrix, Grain Crops

COLLECTION CATEGORY	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPEAT HOURS	DAY	WEEK	MONTH	YEAR	BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION <10	10	20	30	60	100	>100	INFORMATION UNIT SIZE	SPECTRAL RANGE (μ) .5-.6	.6-.8	.8-1.1	1.5-2.3	10-13	PRIORITY ASSIGNMENT	G. E. DISCIPLINE REFERENCE	GOV'T AGENCY (G. E. SOURCE)
I GRAIN CROPS																													
A. SPRING WHEAT																													
1. INVENTORY	1			●				3			APRIL-AUG	330,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	2		●					1			APRIL-AUG	3,330	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.3, 1.4
3. STRESS	3		●				2				MAY-AUG	9,990	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7
B. WINTER WHEAT (NORTHERN AND PACIFIC NW)																													
1. INVENTORY	4			●				3			SEPT-JULY	145,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	5		●					1			MAY-JULY	1,450	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.3, 1.4
3. STRESS	6		●				2				MAY-JULY	4,350	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7
(MIDWEST AND ROCKY MT.)																													
1. INVENTORY	7			●				3			SEPT-JUNE	816,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	8		●					1			APRIL-JUNE	8,160	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.3, 1.4
3. STRESS	9		●				2				APRIL-JUNE	24,480	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7
C. CORN (EASTERN AND MIDWEST)																													
1. INVENTORY	10			●				3			MAY-OCT	719,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	11		●					1			JUNE-OCT	7,190	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.3, 1.7
3. STRESS	12		●				2				JUNE-OCT	21,570	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7
(SOUTHEASTERN)																													
1. INVENTORY	13			●				3			APRIL-SEPT	193,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	14		●					1			MAY-SEPT	1,930	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4, 1.7
3. STRESS	15		●				2				MAY-SEPT	5,790	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7
D. RICE																													
1. INVENTORY	16			●				3			APRIL-NOV	100,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7
2. YIELD	17		●					1			MAY-NOV	1,000	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4, 1.7
3. STRESS	18		●				2				MAY-NOV	3,000	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7

REMARKS AND SPECIAL REQUIREMENTS

AGRICULTURAL PRODUCTION – REPEAT COVERAGE RANGES FROM WEEKLY TO 5 YEARS. STRONG REPEAT REQUIREMENTS FOR 2 WEEK INTERVALS CONFIRMED BY DEPARTMENT OF AGRICULTURE STATISTICAL REPORTING SERVICE. MONTHLY AND QUARTERLY REQUIREMENTS FROM G. E. SOURCE. SPECTRAL COVERAGE STRONGLY DESIRED IN VISIBLE AND REFLECTIVE IR REGIONS W/SOME REQUIREMENT FOR THERMAL IR AND MICROWAVE. SPATIAL RESOLUTION SHOWS STRONG PEAKS FOR 10, 15, AND 30 METER RESOLUTION. DATA APPLIES TO ALL GRAIN AND NON-GRAIN CROPS.

STATISTICAL REPORTING SERVICES INDICATES RESOLUTION TO 1 METER MAY FURNISH BETTER DATA FOR CORRELATION W/GROUND AND LOW ALTITUDE AIRCRAFT DATA.

STRESS ANALYSIS MAY REQUIRE DATA AVAILABLE FROM 1.5-2.3μ CHANNEL. HOWEVER, RESOLUTION DESIRES OUTWEIGH IR DATA AT THIS TIME.

INFORMATION UNIT SIZE – MOST STRINGENT REQUIREMENT IN PARENTHESES

FOLDOUT FRAME 1

FOLDOUT FRAME 2

Table 5. Agronomy Matrix, Non-Grain Crops

COLLECTION CATEGORIES	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPEAT HOUR	DAY	WEEK	MONTH	YEAR	BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION <10	10	20	30	60	100	>100	INFORMATION UNIT SIZE	SPECTRAL RANGE (μ) .5-.6	.6-.8	.8-1.1	1.5-2.3	10-13	PRIORITY ASSIGNMENT	G. E. DISCIPLINE REFERENCES	GOV'T AGENCY (G. E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
II NON-GRAIN CROPS																														
A. SOYBEANS																														
1. INVENTORY	19			●				3			MAY-OCT	925,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7	
2. YIELD	20		●					1			JUNE-OCT	9,250	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4, 1.7	
3. STRESS	21		●				2				JUNE-OCT	27,750	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7	
B. COTTON (EASTERN)																														
1. INVENTORY	22			●				3			APRIL-OCT	679,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7	
2. YIELD	23		●					1			MAY-OCT	6,790	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4, 1.7	
3. STRESS	24		●				2				MAY-OCT	20,370	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7	
(WESTERN)																														
1. INVENTORY	25			●				3			MAY-NOV	203,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4, 1.7	
2. YIELD	26		●					1			JUNE-NOV	2,030	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4, 1.7	
3. STRESS	27		●				2				JUNE-NOV	6,090	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7, 1.7	
C. TOBACCO																														
1. INVENTORY	28			●				3			MARCH-SEPT	304,000	80%			—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4	
2. YIELD	29		●					1			APRIL-SEPT	3,040	1%	—	●	—	—				↓	—	—	—			6	1.2	2.3, 2.6, 1.4	
3. STRESS	30		●				2				APRIL-SEPT	9,120	3%		●	—	—				↓	—	—	—	- - -		6	1.3	2.3, 2.4, 2.7	
III ORCHARDS																														
A. CITRUS (SOUTHEASTERN)																														CITRUS – CITRUS INVENTORY SHOWS A PEAK AT ANNUAL WITH OTHER REQUIREMENTS SIMILAR TO OTHER AGRICULTURE PRODUCTION.
1. INVENTORY	31			●					1		APRIL-OCT	89,600	80%	—	—	—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4	
2. YIELD	32		●					1			APRIL-OCT	1,120.	1%	—	○	—	—	—			↓	—	—	—			6	1.2	2.3, 2.6, 1.4	
3. STRESS	33		●					1			APRIL-OCT	5,600	5%	—	●	—	—				↓	—	—	—			6	1.3	2.3, 2.4, 2.7	
(WESTERN)																														
1. INVENTORY	34			●					1		MAY-NOV	150,400	80%	—	—	—	●	—			(50 x 50 M) COUNTIES	—	—	—			7	1.1, 1.5	2.3, 2.6, 1.4	
2. YIELD	35		●					1			MAY-NOV	1,880	1%	—	●	—	—	—			↓	—	—	—			6	1.2	2.3, 2.6, 1.4	
3. STRESS	36		●					1			MAY-NOV	9,400	5%	—	●	—	—				↓	—	—	—			6	1.3	2.3, 2.4, 2.7	

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areas within individual units, the sample units are potential USDA "ground truth" sites. The ability to extrapolate this ground truth data to large surrounding areas, is thought to be one of the better applications for space acquired remote sensor data. The expressed opinion of some members of the Statistical Reporting Service is that EOS type data will not significantly aid in forecasting national yield, but would be highly significant to their ability to forecast crop yields at the county and state levels, which is rather poorly accomplished at present.

The suggestion was made that, if a high resolution pointable sensor were available, then images should be obtained of specific sample units, rather than sampling at random. This would mean specific target areas for the HRPI imagery. The low percentage sampling rates of some categories, i.e., winter wheat yield (1%), indicates the approximate amount of the resource polygon devoted to the sampling requirement.

The stress requirement is more uniformly spread across the total area polygon. Conversations with representatives of the USDA indicate that a 2-5% sampling of the crop area every two weeks would be an immense help in detecting and monitoring the conditions of stress in crops. It was assumed that a 3% requirement is uniformly distributed across the crop area.

Grazing lands and soil conditions were requested by a number of agencies for several classes. Grazing lands (grasslands) appear under Agronomy and Forestry while soil conditions have various requirements under Agronomy, Geology, and Hydrology. All of these requirements are consolidated into the collection categories given in the matrix in Table 6.

The grasslands includes an inventory and stress category. The inventory category includes a determination of the amount of grasslands available and a determination of stressed areas. The stress monitor category is a monitoring of the stressed areas identified in the inventory. These sites are estimated to be approximately 3% of the total area at any one time; however, they are specific sites that must be imaged rather than an arbitrary 3%.

The soil conditions requirements were wide-spread among the disciplines and user agencies. The requirements ranged from infrequent surveys of small areas to surveys of the entire U.S. at three month

Table 6. Grasslands, Soil, Forest Matrix

COLLECTION CATEGORIES	CAT. NO.	INSTR.			COVERAGE REPEAT						OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION							INFORMATION UNIT SIZE	SPECTRAL RANGE (μ)					PRIORITY ASSIGNMENT	DISCIPLINE REFERENCE (G.E. SOURCE)	GOV'T AGENCY (G.E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
		TM	HRPI	EITHER	HOUR	DAY	WEEK	MONTH	YEAR	BY SITE				<10	10	20	30	60	100	>100		.5-.6	.6-.8	.8-1.1	1.5-2.3	10-13				
IV GRASSLANDS																														
1. INVENTORY	37			●				1			APRIL-NOV	1,323,200	80%				●				50 x 50 M	—	—	—			5	1.11, 3.10, 2.3	1.2-1.5, 1.7, 2.1, 2.2	RANGELAND - DATA ON REPEAT COVERAGE, SPATIAL, AND SPECTRAL REQUIREMENTS MINIMAL FOR THIS RESOURCE. PRESENTED DATA IS BEST GUESS FOR THIS STUDY.
2. STRESS MONITOR	38		●				2				APRIL-NOV	49,620	3%		●							—	—	—	—		5	1.12,3.11,2.3, 2.4	1.4 1.5, 1.7	
V SOIL																												1.6		
1. SURVEY	39			●				3			NO SNOW	7,200,000	90%				●				50 x 50 M	—	—	—			5	5.1, 6.8, 5.2, 1.10	1.1-1.7, 2.1, 2.2, 2.7	
2. MOISTURE (RANGELAND)	40	●						1			NO SNOW	1,488,000	90%				●					—	—	—	—	—	5	1.7, 1.9	1.4, 1.5	
3. MOISTURE (SITES)	41	●					2				NO SNOW	40,000	1%				●					—	—	—	—	—	6	1.7	2.7	
VI FOREST																														
A. CONIFER (EASTERN)																														
1. INVENTORY	42			●					1		NO SNOW	992,250	90%		—	—	●	—			50 x 50 M	—	—	—			6	3.1, 3.4	1.2, 1.3, 1.5, 1.7, 2.1	FORESTRY PRODUCTION - REPEAT COVERAGE RANGES FROM WEEKLY TO FIVE YEARS WITH STRONG PEAK DESIRE FOR ANNUAL. SPECTRAL COVERAGE DESIRED FROM VISUAL THROUGH MICROWAVE WITH STRONGEST PEAKS IN VISUAL AND REFLECTIVE IR. FIRE AND FIRE ASSESSMENT HAVE VERY STRONG REQUIREMENTS FOR THERMAL IR. SPATIAL RESOLUTION HAS PEAK REQUIREMENTS AT 10, 15, AND 30 METERS WITH THE HIGHER RESOLUTIONS ASSOCIATED WITH DISEASE AND YIELD ESTIMATES. FIRE ASSESSMENT MAY REQUIRE HIGHER RESOLUTION THAN SPECIFIED, DEFINITIVE REQUIREMENTS NOT ESTABLISHED.
2. TIMBER YIELD	43		●						1		NO SNOW	11,025	1%	—	●	—						—	—				6	3.2	1.2, 1.7, 2.1	
3. STRESS	44		●					1			APRIL-SEPT	33,075	3%	—	●	—						—	—	—			7	3.3	1.2, 1.5, 1.7, 2.1, 2.4	
4. FIRE CONDITIONS	45	●						1			JUNE-SEPT	882,000	80%		—	—	●	—				—	—	—	—	—	6	3.9	1.2, 1.5, 1.7	
5. FIRE ASSESSMENT		●			(1) 4						(DURING FIRE)		SITE		—	—	●					—	—	—	—	- -	10			
(WESTERN)																														
1. INVENTORY	46			●					1		NO SNOW	868,500	90%		—	—	●	—				—	—	—			6	3.1, 3.4	1.2, 1.3, 1.5, 1.7, 2.4	
2. TIMBER YIELD	47		●						1		NO SNOW	9,650	1%	—	●	—						—	—				6	3.2	1.2, 1.7, 2.1	(1) NOT AMENABLE TO EOS MISSION.
3. STRESS	48		●					1			APRIL-SEPT	27,950	3%	—	●	—						—	—	—			7	3.3	1.2, 1.5, 1.7, 2.1, 2.4	
4. FIRE CONDITIONS	49	●						1			JUNE-OCT	772,000	80%		—	—	●	—				—	—	—	—	—	6	3.9	1.2, 1.5, 1.7	
5. FIRE ASSESSMENT		●			(1) 4						(DURING FIRE)		SITE		—	—	●						—	—	—	- -	10			
B. HARDWOOD																														
1. INVENTORY	50			●					1		MARCH-NOV	745,200	90%		—	—	●	—				—	—	—			6	3.1, 3.4	1.2, 1.3, 1.5, 1.7, 2.1	
2. TIMBER YIELD	51		●						1		MAY-OCT	8,280	1%	—	●	—						—	—				6	3.2	1.2, 1.7, 2.1	
3. STRESS	52		●					1			MAY-SEPT	24,840	3%	—	●	—						—	—	—			7	3.3	1.2, 1.5, 1.7, 2.1, 2.4	
4. FIRE CONDITIONS	53	●						1			JUNE-OCT	662,400	80%		—	—	●	—				—	—	—	—	—	6	3.9	1.2, 1.5, 1.7	
5. FIRE ASSESSMENT		●			(1) 4						(DURING FIRE)		SITE		—	—	●						—	—	—	- -	10			
C. MIXED FOREST																														
1. INVENTORY	54			●					1		APRIL-OCT	200,700	90%		—	—	●	—				—	—	—			6	3.1, 3.4	1.2, 1.3, 1.5, 1.7	
2. TIMBER YIELD	55		●						1		MAY-OCT	2,230	1%	—	●	—						—	—				6	3.2	1.2, 1.7	
3. STRESS	56		●					1			APRIL-SEPT	6,690	3%	—	●	—						—	—	—			7	3.3	1.2, 1.5, 1.7, 2.1, 2.4	
4. FIRE CONDITIONS	57	●						1			JUNE-OCT	178,400	80%		—	—	●	—				—	—	—	—	—	6	3.9	1.2, 1.5, 1.7	
5. FIRE ASSESSMENT		●			(1) 4						(DURING FIRE)		SITE		—	—	●						—	—	—	- -	10			

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intervals. The latter, being the most stringent requirement, was selected to satisfy the requirements for soil capability, soil erosion, soil classification, rock type, and soil properties. Special categories were made for soil moisture measurements which are aided by thermal IR channel of the TM. These soil moisture requirements include a measurement of the moisture conditions in the rangeland (grasslands) area, and a monitoring of specific sites within the croplands categories. These latter sites make up approximately 1% of the total cropland.

3.4.2.2 <u>Forestry</u>

The Forestry categories contain timber status, fire conditions, precipitation, and grasslands status. The grasslands have been previously discussed under Agronomy. The Forestry categories were broken down into the forest type (conifer or hardwood) and geographical region (Eastern or Western) as shown in Table 6. Only the conifer categories were divided geographically primarily due to the seasonal fire hazards. A set of mixed forest categories was included to reflect the forestry conditions in the Great Lakes region.

The Forestry categories contain inventory, yield, and stress similar to the Agronomy categories; however, since forests are a more permanent resource, the cycle times are longer. Many of the agencies requirements for fire conditions and assessment, however, had cycle times and coverage requirements that were incompatible with the EOS system coverage. There were several requirements for fire conditions surveys at a one month interval which were chosen for the EOS collection categories. These categories had different seasonal requirements to reflect the fire hazard conditions in the Eastern and Western United States.

The requirements for precipitation and evaporation were contained in the Agronomy, Forestry, and Hydrology classes. Though contained in three classes, the agency requirements as described in the TERSSE study were minimal. These requirements were augmented with information from other sources to define the requirements given in Table 7. These requirements cover precipitation in the form of rain and snow. The rainfall categories require moisture content information which is aided by the thermal IR of the TM. The snow accumulation data is reflective

Table 7. Precipitation, Mapping Matrix

COLLECTION CATEGORIES	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPEAT HOUR	DAY	WEEK	MONTH	YEAR	BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION <10	10	20	30	60	100	>100	INFORMATION UNIT SIZE	SPECTRAL RANGE (μ) .5-.6	.6-.8	.8-1.1	1.5-2.3	10-13	PRIORITY ASSIGNMENT	DISCIPLINE REFERENCE (G.E. SOURCE)	GOV'T AGENCY (G.E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
VII PRECIPITATION																														
A. RAIN																														WATER RESOURCES – REPORT COVERAGE HOURLY TO ANNUAL WITH PEAK AT 18 DAYS. G.E. REPORTS WEEKLY REQUIRED. SPECTRAL RANGE INCLUDES VISUAL THROUGH MICROWAVE W/SIGNIFICANT REQUIREMENTS IN ALL REGIONS. RESOLUTION RANGE FROM 3 METERS TO 1500 METERS, PEAKS AT 10, 15, 30 AND 100. 30 METER HAS HIGH ACCEPTABILITY POTENTIAL. SNOW DISTRIBUTION DOES NOT REQUIRE THERMAL IR, OTHER SNOW DATA WOULD NEED THIS SPECTRAL COVERAGE.
1. JAN., FEB., MARCH	58	●					1				WINTER	885,000	25%	—	—	—	●	—	—	—	1 x 1 KM	—	—	—	—	—	5	1.3, 1.7, 1.8	1.1, 1.2, 1.3	
2. APRIL, MAY, JUNE	59	●					1				SPRING	735,000	25%	—	—	—	●	—	—	—	↓	—	—	—	—	—	5	1.9, 1.12	1.4, 2.1, 2.2	
3. JULY, AUG., SEPT.	60	●					1				SUMMER	912,500	25%	—	—	—	●	—	—	—	↓	—	—	—	—	—	5	2.5, 3.3, 3.5	2.4, 2.6, 2.7	
4. OCT., NOV., DEC.	61	●					1				FALL	88,750	25%	—	—	—	●	—	—	—	↓	—	—	—	—	—	5	3.6, 3.7, 3.8	4.1, 5.1	
B. SNOW																												3.9, 3.11, 3.12		
1. NOV. AND MARCH	62			●			1				NOV., MAR.	302,000	25%	—	—	—	●	—	—	—	↓	—	—	—	- -	- -	6	4.2, 4.4		
2. DEC. AND FEB.	63			●			1				DEC., FEB.	1,005,500	25%	—	—	—	●	—	—	—	↓	—	—	—	- -	- -	6	5.1, 6.1, 6.7		
3. JAN.	64			●			1				JAN.	1,155,750	25%	—	—	—	●	—	—	—	↓	—	—	—	- -	- -	6	6.9		
VIII MAPPING																														
A. PHYSIOGRAPHY/LAND USE																														MAPPING SERVICES – REPEAT COVERAGE HAS STRONG PEAK AT 5 YEARS WITH SMALLER PEAK AT ONE (1) YEAR. ONE YEAR REQUIREMENT FROM G.E. REPORT. SPECTRAL RANGE INCLUDES VISUAL THRU MICROWAVE. MAJOR REQUIREMENTS FOR VISUAL AND REFLECTIVE IR. RESOLUTION RANGES FROM 3 TO 100 METERS WITH STRONG PEAK AT 20 METERS, ACCEPTABILITY AT 30 METERS. TRANSPORTATION PLANNING – REPEAT COVERAGE RANGES FROM WEEKLY TO ANNUAL WITH PEAK AT ANNUAL. SPECTRAL RANGE SHOWS PEAK DESIRES FOR VISUAL AND REFLECTIVE IR. RESOLUTION REQUIREMENT HAS STRONG PEAK AT 15 METERS, RANGES FROM 2 METERS TO 100 METERS.
1. EASTERN	65	●							1		NO SNOW	632,000	100%	—	—	—	●	—	—		50 x 50 M	—	—	—			4		1.1, 1.2, 1.3	
2. SOUTH EASTERN	66	●							1		NO SNOW	1,090,000	100%	—	—	—	●	—	—		↓	—	—	—			4	1.13, 3.7	1.4, 1.5, 1.7	
3. MIDWESTERN	67	●							1		NO SNOW	1,180,000	100%	—	—	—	●	—	—		↓	—	—	—			4	4.1, 4.4	2.1, 2.2, 2.5	
4. GULF	68	●							1		NO SNOW	1,230,000	100%	—	—	—	●	—	—		↓	—	—	—			4	4.9, 4.11		
5. ROCKY MOUNTAIN	69	●							1		NO SNOW	1,051,000	100%	—	—	—	●	—	—		↓	—	—	—			4	5.2-5.3		
6. SOUTHWESTERN	70	●							1		NO SNOW	613,000	100%	—	—	—	●	—	—		↓	—	—	—			4	5.9-5.11		
7. NORTHERN	71	●							1		NO SNOW	652,000	100%	—	—	—	●	—	—		↓	—	—	—			4			
8. INTERMOUNTAIN	72	●							1		NO SNOW	667,000	100%	—	—	—	●	—	—		↓	—	—	—			4			
9. CALIFORNIA	73	●							1		NO SNOW	431,000	100%	—	—	—	●	—	—		↓	—	—	—			4			
10. PACIFIC NORTHWEST	74	●							1		NO SNOW	453,000	100%	—	—	—	●	—	—		↓	—	—	—			4			
B. URBAN/TRANSPORTATION																												5.1, 5.5, 5.4	1.1, 1.4	
1. SELECT SITES	75		●						1		NO SNOW	97,850	95%	—	●	—	—	—	—		50 x 50 M	—	—	—				5.6, 5.9, 6.1		
																												6.2, 6.7, 6.9-		
																												6.11, 4.8, 4.11		
																												4.2, 5.2		

and the requirements can be satisfied by either sensor. The coverage and frequency requirements are dictated by trying to supply enough information to be useful in weekly forecasts and reports.

3.4.2.3 Geography

The disciplines under Geography that are amenable to remote imaging are mapping disciplines. These include both physiographic mapping and land use mapping. Although different use may be made of the product, the requirements for physiographic and land use mapping are similar enough to be contained in the same collection categories. The exception to this is the urban and transportation mapping which is concentrated in a few pilot areas. These require high resolution and are assigned to the HRPI as shown in Table 7.

3.4.2.4 Geology

The Geology class contains soil and rock information, mineral surveys, geological process, properties, and land forms, geothermal resources, and glaciers. The soil and rock type information is contained in the soil survey category previously described. The geological process, properties, land forms, and tectonics are long cycle survey requirements which are satisfied by the mapping categories which cover the entire U.S. once a year. No additional categories were developed for these requirements.

The mineral deposits categories were broken down into the prime metals identified by the ERPO Program Plan and the prime energy minerals with geothermal resources listed along with the energy minerals. The requirements for these categories are given in Table 8.

The major metals were identified as iron, copper, and nickel. Nickel is mined at only two locations in the United States--one in the East and one in the West. These areas will be monitored on a yearly basis. The iron and copper resources require an inventory or exploration of the potential producing areas on a 2-5 year cycle. Major mining operations are then monitored three times per year.

The energy minerals are treated like the major metals with inventory and monitor categories. The coal and oil and gas are divided into Eastern and Western divisions to reflect the differences in the types

COLLECTION CATEGORIES	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPORT HOUR	COVERAGE REPORT DAY	COVERAGE REPORT WEEK	COVERAGE REPORT MONTH	COVERAGE REPORT YEAR	COVERAGE REPORT BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION <10	RESOLUTION 10	RESOLUTION 20	RESOLUTION 30	RESOLUTION 60	RESOLUTION 100	RESOLUTION >100	INFORMATION UNIT SIZE	SPECTRAL RANGE (μ) .5-.6	SPECTRAL RANGE (μ) .6-.8	SPECTRAL RANGE (μ) .8-1.1	SPECTRAL RANGE (μ) 1.5-2.3	SPECTRAL RANGE (μ) 10-13	PRIORITY ASSIGNMENT	DISCIPLINE REFERENCE (G.E. SOURCE)	GOV'T AGENCY (G.E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
IX MINERALS																														
A. MAJOR METALS																														
1. IRON																														
a. INVENTORY	76			●					5		NO SNOW	432,250	95%				●				50 x 50 M	—	—	—			5	5.3, 5.4	1.1, 1.6	MINERAL RESOURCES - DATA ON SPECTRAL, SPECIAL AND REPEAT COVERAGE REQUIREMENTS IS INADEQUATE FOR EVALUATION. PRESENTED DATA ARE BEST GUESS DEVELOPED FOR PURPOSES OF THIS STUDY. THERMAL IR REQUIREMENTS FOR URANIUM AND GEOTHERMAL ARE BASED ON POSSIBILITY OF ASSOCIATED THERMAL ANOMOLIES. RESOLUTIONS ARE INDICATED AS BELONGING TO EITHER A TM OR HRPI WITHOUT ANTICIPATING A RANGE OF DESIRED VALUES.
b. MONITOR	77		●					3			NO SNOW	10,800	2.5%		●						↓	—	—	—			5	5.10, 2.35	1.6	
2. COPPER																														
a. INVENTORY	78			●					2		NO SNOW	916,750	95%				●				↓	—	—	—			5	5.3, 5.10	1.1, 1.6	
b. MONITOR	79		●					3			NO SNOW	11,000	1.2%		●						↓	—	—	—			5	5.3, 2.35	1.6	
3. NICKEL																														
a. MONITOR	80		●						1		NO SNOW	15,580	95%		●						↓	—	—	—			4	5.3, 5.10, 2.35	1.1, 1.6	
B. ENERGY MINERALS																														
1. COAL (EASTERN)																														
a. INVENTORY	81			●					1		NO SNOW	465,000	95%				●				↓	—	—	—			6	5.3, 5.10	1.1, 1.6	
b. MONITOR	82		●					3			NO SNOW	4,650	1%		●						↓	—	—	—			6	5.3, 2.35	1.6	
2. COAL (WESTERN)																														
a. INVENTORY	83			●					1		NO SNOW	873,000	95%				●				↓	—	—	—			7	5.3, 5.10	1.1, 1.6	
b. MONITOR	84		●					3			NO SNOW	8,730	1%		●						↓	—	—	—			6	5.3, 2.35	1.6	
3. OIL/GAS (EASTERN)																														
a. INVENTORY	85			●					1		NO SNOW	407,000	95%				●				↓	—	—				7	5.3, 5.10	1.1, 1.6	
b. MONITOR	86		●					6			NO SNOW	4,070	1%		●						↓	—	—				7	5.3, 2.35	1.6	
4. OIL/GAS (WESTERN)																														
a. INVENTORY	87			●					1		NO SNOW	2,012,000	95%				●				↓	—	—				7	5.3, 5.10	1.1, 1.6	
b. MONITOR	88		●					6			NO SNOW	20,120	1%		●						↓	—	—				7	5.3, 2.35	1.6	
5. URANIUM																														
a. INVENTORY	89			●					2		NO SNOW	850,000	95%				●				↓	—	—	—	—	—	5	5.3, 5.10	1.1, 1.6	
b. MONITOR	90		●					3			NO SNOW	12,750	1.5%		●						↓	—	—	—	—		5	5.3, 2.35	1.6	
6. GEOTHERMAL																														
a. INVENTORY	91	●							1		NO SNOW	8,000,000	100%		●						1 x 1 KM	—	—	—	—	—	6	5.6	1.1, 1.4	
b. MONITOR	92	●						6			NO SNOW	80,000	1%		●						↓	—	—	—	—	—	5	5.6	1.1, 1.2	
X. HYDROLOGY																													1.1, 1.2, 1.3	HYDROLOGY - REPEAT COVERAGE REQUIREMENTS RANGE FROM HOURLY TO ANNUAL W/SLIGHT PEAK AT 18 DAY AND STRONG PEAK AT MONTHLY. RANGE OF RESOLUTION IS FROM 2 TO 1000 METERS W/PEAK VALUES AT 10, 15 AND 100 METERS. ACCEPTABILITY OF 30 METER RESOLUTION HIGH. SPECTRAL REQUIREMENTS OPTICAL THRU THERMAL IR, WITH THERMAL IR VERY DESIRABLE. LOW RESOLUTION DESIRED FOR GLACIER OBSERVATIONS.
A. SURFACE WATER/WET LANDS																												1.3, 1.5, 1.12,	1.4, 1.5, 1.6	
1. INVENTORY	93	●							1		MAR. - OCT.	8,000,000	100%	—	—	—	●	—	—	—	50 x 50 M	—	—	—	—	—	5	2.29, 4.4, 6.1	1.7, 2.1, 2.2	
2. MONITOR	94		●					1			ALL YEAR	480,000	70%	—	●	—	—	—	—	—	↓	—	—	—	—		6	6.2, 6.3, 6.4	2.3, 2.7, 4.1	
B. GLACIERS																												6.5, 6.7, 6.13	5.1	
1. MONITOR	95	●						3			ALL YEAR	11,000	100%	—	—	—	●				↓	—	—	—	—	—	5	6.12		

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of coal and oil found in different geographic locations. The dividing line for this separation runs roughly along the Mississippi River.

The geothermal resource areas have similar requirements. Specific areas are required to be monitored semi-annually. The inventory category includes the entire United States. These categories require the thermal IR channel of the TM to locate and survey the thermal anomalies associated with the geothermal resource.

3.4.2.5 Hydrology

The Hydrology discipline includes water inventory and conditions, precipitation and evaporation, soil moisture, glaciers, and wetlands. The precipitation and evaporation and soil moisture requirements have been covered previously. The remaining requirements are shown in Table 8.

The wetlands requirements have been consolidated into the surface water and estuaries categories to include the inland and coastal wetlands. The surface water discipline contains an inventory and monitoring category. The inventory category requires an annual survey of the entire U.S., while the monitor category concentrates on a few specific lakes, reservoirs, and river basins once a month. There are requirements for once a day coverage of flood and storm damage which exceeds the capability of EOS. Emergency requirements will be handled on a priority basis to the extent that the system is capable.

3.4.2.6 Coastal Zones

The coastal zone class is a portion of the Oceanography discipline identified in the G.E. study. This class is considered separately since it is applicable to the EOS-A mission. Coastal zone requirements include near shore bottom topography, circulation patterns, coastal upwelling, dredging and construction, beach morphology, and outfall and river discharge. These requirements break out into geographical regions or features such as those requirements applicable to the entire coastline, the Great Lakes, major estuaries, and major river mouths. The requirements in Table 9 reflect this breakdown.

Table 9. Coastal Zones Matrix

COLLECTION CATEGORIES	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPEAT HOUR	DAY	WEEK	MONTH	YEAR	BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ.KM.)	AREA COVERAGE	RESOLUTION <10	10	20	30	60	100	>100	INFORMATION UNIT SIZE	PRIORITY ASSIGNMENT	DISCIPLINE REFERENCE (G.E. SOURCE)	GOVERNMENT AGENCY (G.E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
XI COASTAL ZONES																									
A. COASTLINE (EASTERN)																									COASTAL OCEANOGRAPHY - REPEAT COVERAGE REQUIREMENTS RANGE FROM HOURLY TO ANNUAL SLIGHT PEAK AT 18 DAYS. G.E. REPORTS PEAKS AT 6 HRS AND 1 WEEK. RESOLUTION RANGE FROM 3 METERS TO 1500 METERS PEAKS AT 10, 35 AND 100 METERS. 30 METER STRONG ACCEPTABILITY. SPECTRAL RANGE VISUAL, THERMAL IR AND MICROWAVE WITH SIGNIFICANT REQUIREMENTS IN ALL SPECTRAL REGIONS. REFLECTIVE IR WITH HIGH-RESOLUTION OF HRPI REQUIRED MORE THAN THERMAL IR FOR CIRCULATION AND UPWELLING I.D. NO IDENTIFIED SPECTRAL REQUIREMENTS FOR COASTAL CONSTRUCTION, RESOLUTION ASSUMED TO BE PRIME.
1. BOTTOM TOPOGRAPHY	96	●						3			MAR-OCT.	173,000	50%				●				(50 x 50 M)	4	7.18	4.1	
2. CIRCULATION/UPWELLINGS	97		●				1				ALL YEAR	69,200	20%		●							6	7.20, 7.19, 7.27	1.1, 1.2, 1.4	
3. CONSTRUCTION	98		●							3		SITE	95%		●							6	7.26	5.1	
B. COASTLINE (FLORIDA)																									
1. BOTTOM TOPOGRAPHY	99	●						3			ALL YEAR	117,000	80%				●					4			
2. CIRCULATION/UPWELLING	100		●				1				ALL YEAR	44,000	30%		●							6			
3. CONSTRUCTION	101		●							3		SITE	95%		●							6			
C. COASTLINE (GULF)												216,000													
1. BOTTOM TOPOGRAPHY	102	●						3			ALL YEAR	108,000	50%				●					4			
2. CIRCULATION/UPWELLING	103		●				1				ALL YEAR	43,200	20%		●							6			
3. CONSTRUCTION	104		●							3		SITE	95%		●							6			
D. COASTLINE (PACIFIC)												270,000													
1. BOTTOM TOPOGRAPHY	105	●						3			ALL YEAR	135,000	50%				●					4			
2. CIRCULATION/UPWELLING	106		●				1				ALL YEAR	54,000	20%		●							6			
3. CONSTRUCTION	107		●							3		SITE.	95%		●							6			
E. GREAT LAKES																									GREAT LAKES - NO SPECIFIC DATA ON REPEAT COVERAGE, SPECTRAL BANDS OR SPACIAL RESOLUTION. ASSUMED TO BE SAME AS COASTLINES AND RIVER ICE REQUIREMENTS. SEE EARTHSAT REPORT.
1. BOTTOM TOPOGRAPHY	108	●						3			MARCH-OCT.	285,000	80%				●					4	6.2, 6.3, 7.18, 7.27	1.3, 4.1	
2. SURFACE ICE	109		●				1				NOV.-MARCH	26,000	95%		●							8		4.1	
F. ESTUARIES/WET LANDS																									
1. CIRCULATION	110		●				1				ALL YEAR	238,000	80%		●							4	7.19, 2.19, 6.13	1.1, 1.3, 1.5	
G. RIVERS																								2.2, 2.7	RIVER DISCHARGE - REPEAT COVERAGE RANGE HOURLY TO ANNUAL. G.E. REPORTS AS PEAK AT 6 HRS AND 4 MONTHS. SPECTRAL DESIRED VISUAL THROUGH REFLECTIVE I.R. RESOLUTION PEAKS AT 10, 15 AND 30 METERS HIGHER RESOLUTION (10M) HIGHLY DESIRABLE.
1. DISCHARGE	111		●					4			ALL YEAR	73,000	95%		●							7	7.23	1.2, 1.3	

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The percentage of the area coverage required was difficult to assess and the number shown reflects the best guesses at this time. Extra emphasis was placed on the Florida coastline since this is a scene for many studies. The requirements for circulation and upwelling were very similar and they were consolidated into a single category. Many requirements for circulation and upwelling were identified with coverage at six-hour intervals to correspond with tidal changes. This requirement is clearly outside the capability of the EOS so the next most stringent requirement of one-week repeat coverage intervals was chosen. At this interval the same data could also be useful for measurements of beach morphology. Dredging and construction sites were required to be monitored three times during construction.

The Great Lakes region requires bottom topography similar to the coastlines. However, in addition, it is desired to obtain data on surface ice at a repeat coverage cycle sufficient to be of value to commercial traffic on the lakes. This repeat coverage cycle places a stringent requirement on this category.

Estuaries and river mouths are areas of concentrated data requirements. The estuaries require circulation measurements similar to the coastline requirements but with a higher percentage of area coverage. The one week repeat cycle chosen allows this data to also be useful for coastal wetlands monitoring as mentioned earlier.

3.4.2.7 Environmental Quality

Many of the parameters of interest to environmental quality are not measurable by remote sensing or require specially designed instruments. For this reason this class was not included in the polygon definitions; however, some data can be obtained with the EOS-A sensor configuration and these data are described in the following paragraphs, and shown in Table 10.

3.4.2.7.1 Water

Water pollution parameters that are detectable from above the surface of the water may be amenable to remote sensing. These parameters include petroleum leakage or spills, particles suspended in the water, plankton and algae concentrations, and thermal anomalies.

COLLECTION CATEGORY	CAT. NO.	INSTR. TM	INSTR. HRPI	INSTR. EITHER	COVERAGE REPEAT HOURS	DAY	WEEK	MONTH	YEAR	BY SITE	OBSERVATION SEASON	APPROX. AREA (SQ. KM.)	AREA COVERAGE	RESOLUTION <10	10	20	30	60	100	>100	INFORMATION UNIT SIZE	SPECTRAL RANGE (μ) .5-.6	.6-.8	.8-1.1	1.5-2.3	10-13	PRIORITY ASSIGNMENT	G. E. DISCIPLINE REFERENCE	GOV'T AGENCY (G. E. SOURCE)	REMARKS AND SPECIAL REQUIREMENTS
XII ENVIRONMENTAL QUALITY																														
A. WATER																														
1. MAJOR RIVERS AND LAKES												375,000																		ENVIRONMENTAL QUALITY _ REPORT
a. PETROLEUM (SPILLS)		●						1			ALL YEAR	↓					●				50 x 50 M	—	—	—	—	—		2.20	1.1, 1.3, 1.4, 2.2	REQUIREMENTS HOURLY TO ANNUAL WITH PEAK AT 18 DAY. RESOLUTION 3 TO 300
b. SUSPENDED PARTICLES		●						1			↓	↓					●				↓	—	—	—	—	—		2.28	1.1, 1.3, 1.4, 2.2, 5.1	METERS WITH PEAKS AT 15, 30, AND 100
c. PLANKTON/ALGAE				●				1			↓	↓					●				↓	—	—	—				2.30-2.32	1.1, 1.3, 2.2	METERS. ALL SPECTRAL BANDS REQUIRED.
2. SURVEY - U.S.											↓	9,100,000																		
a. PETROLEUM (SPILLS)		●						3			↓	↓					●				1 x 1 KM	—	—	—	—	—		2.20	1.3, 1.4, 2.2	
b. SUSPENDED PARTICLES		●						3			↓	↓					●				↓	—	—	—	—	—		2.28	1.3, 1.4, 2.2	
c. PLANKTON/ALGAE				●				3			↓	↓					●				↓	—	—	—				2.30-2.32	2.2	
d. THERMAL ANOLOMIES		●						3			↓	↓					●				↓				—	—		2.17	1.3, 1.4, 2.2	
B. LAND											↓																			
1. DESPOILED LAND			●						1		↓	2,100,000									50 x 50 M	—	—	—				2.35	1.4, 1.5, 2.2	URBAN AREAS, MINES, CROPLAND, MAJOR RIVER BASINS SOLID WASTE - THERMAL
2. SOLID WASTE			●					3			↓	SITES			●						↓	—	—	—	—	—		2.37	3.0	CHANNELS HAVE BEEN USED FOR SOLID WASTE DETECTION, HOWEVER HIGH
C. AIR																														
1. HEAT (INDUSTRIAL)		●					2				SUMMER	260,000					●				1 x 1 KM				—	—		2.14	3.0	RESOLUTION IS MORE VALUABLE PARAMETER.
2. AEROSOLS		●				1					ALL YEAR	260,000					●				50 x 50 M	—	—	—	—	—		2.15	4.1	
XIII OCEANOGRAPHY																														
1. OCEAN TEMPERATURE		●						1			ALL YEAR	60×10^6					●				5 x 5 KM				—	—		7.1	4.1	
2. OCEAN CIRCULATIONS				●			(1)	1			ALL YEAR	(360×10^6) 230,000					●				(5 x 5 KM) 50 x 50 M	—	—	—	—	—		7.5	3.0, (4.1), 5.1	( ) INDICATES WEEKLY OCEAN SURVEY REQUIREMENTS DAILY COVERAGE OF N. ATLANTIC
3. ICEBERGS				●		1					MAY-JUNE	36×10^6					●				5 x 5 KM	—	—	—				7.12	4.1	
4. ORGANISM		●						1			ALL YEAR	60×10^6					●				2 x 2 KM	—	—	—	—	—		7.17	4.1	
5. WATER COMPOSITION		●						1			ALL YEAR	60×10^6					●				5 x 5 KM	—	—	—	—	—		7.10	4.1	REPEAT COVERAGE NOT PRESENTLY IDENTIFIED.
6. SURFACE STRUCTURE		●									ALL YEAR						●					—	—	—	—	—				

The water pollution categories are contained in two geographical areas. The major rivers and lakes are identified for monitoring of their condition on a monthly basis. A survey of the entire U.S. is also included at three month intervals. Notice that thermal anomalies are contained only in the survey areas since its monitor and survey requirements are identical. Some requirements were also found for coastline monitoring; however, these are adequately covered under the coastal zones categories.

The water pollution categories generally require low resolution wide spectral band coverage. All categories receive substantial data from the IR bands except the plankton and algae concentrations which can be determined with the aid of the color variations in the visible band.

3.4.2.7.2 Land

The land quality categories are perhaps most amenable to remote sensing with an EOS-A sensor configuration. The two categories that stand out are despoiled land and solid waste deposition. These categories can generally be satisfied by conventional photo-interpretative techniques with high resolution visible band imagery.

The areas of interest for identifying and monitoring despoiled land are urban areas, mining areas, croplands, and major river basins. Solid waste areas have been identified only as selected sites. Thermal IR data is of aid in determining the extent of some solid wastes; however, it was felt that resolution was the overriding requirement.

3.4.2.7.3 Air

Air pollution parameters are perhaps the most difficult to measure. Two parameters that do have the potential of being observed with the EOS-A sensors are industrial heat and atmospheric aerosols. The heat category can be measured over urban areas with the thermal IR channel of the thematic mapper. The scattering properties of aerosols can be observed in the visible and IR ranges.

The resolution requirements of the air pollution categories is generally low; however, the desired repeat cycle is quite high. A one day requirement for aerosols is outside the capability of the presently configured EOS and a two week requirement for industrial heat will have a low accomplishment factor. Coverage of these items may not be suitable for an applications requirement with the present EOS configuration.

3.4.2.8 Oceanography

The information required for oceanography suffers from the same drawbacks as the water pollution categories in that only a few surface related items are amenable to observation by remote sensing. This class was, therefore, also deleted from the polygon definition. The items identified in the G. E. TERSSE study that are amenable to obtaining useful data by remote sensing include:

- Ocean temperature
- Ocean circulation
- Icebergs
- Organism (phytoplankton, zooplankton, carnivores)
- Water composition

The requirement for these categories is given in Table 10.

Ocean temperature can be measured with the thermal IR channel of the TM. Ocean circulation has some requirements for high resolution and some for thermal IR information. These requirements are, perhaps, compensating such as either sensor can provide useful data. Iceberg data is obtained in the visible band but the required repeat period is difficult to meet unless the area of interest is very far North. Organisms and water composition will require information from all bands. The most stringent requirement for these categories may be the large area to be covered in a relatively short time.

The requirement for surface conditions was recognized in the G. E. discipline listing but not indicated in the user agency requirements. This category was added to the matrix although not all the collection requirements are given.

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